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DRAFT

Work Plan for a Risk Based Phase III RAP/Phase IV RIP at Landfill B

Transition Tier IA Site
Permit Number 78717
Disposal Site Number 1-0000054

Westover Air Reserve Base
Massachusetts

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

439th SPTG/CEV
Westover Air Reserve Base
Chicopee, Massachusetts

January 1997

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WORK PLAN FOR A RISK BASED PHASE III RAP/PHASE IV RIP AT LANDFILL B

TRANSITION TIER IA SITE
PERMIT NUMBER 78717
DISPOSAL SITE NUMBER 1-0000054

WESTOVER AIR RESERVE BASE
MASSACHUSETTS

Prepared for

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

and

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Prepared by

Parsons Engineering Science, Inc.
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µg/L	Microgram per liter
2-D	Two-dimensional
AFCEE	Air Force Center for Environmental Excellence
ARB	Air Reserve Base
AUL	Activity and Use Limitation
bgs	Below ground surface
BRA	Baseline risk assessment
BTEX	Benzene, toluene, ethylbenzene, and xylene
CAAA	Corrective Action Alternatives Analysis
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMR	Code of Massachusetts Regulations
COPC	Chemical of potential concern
CSA	Comprehensive Site Assessment
CSM	conceptual site model
DCA	Dichloroethane
DCB	Dichlorobenzene
ECS	Environmental Compliance Services, Inc.
ER	Electrical resistivity
ES	Engineering-Science, Inc.
FS	Feasibility Study
ft/day	Feet per day
ft/ft	Foot per foot
Geotech	Chem-Nuclear Geotech, Inc.
GPR	Ground-penetrating radar
ISA	Initial Site Assessment
LEL	Lower explosive limit
LSP	Licensed site professional
MADEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
MEK	Methyl ethyl ketone
mg/kg	Milligrams per kilogram
mg/L	Milligram per liter
MGL	Massachusetts General Law
MNHA	Massachusetts Natural Heritage Atlas
MOC	Method of characteristic
msl	Mean see level
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
OBG	O'Brien & Gere Engineers, Inc.
ORP	Oxidation/reduction potential
Parsons ES	Parsons Engineering Science, Inc.
PCA	Tetrachloroethane
PCE	Tetrachloroethene
ppbv	Parts per billion, volume per volume
ppmv	Parts per million, volume per volume

POC	Point of compliance
PVC	Polyvinyl chloride
RAO	Remedial Action Outcome
RAP	Remedial Action Plan
RI	Remedial Investigatiokn
RIP	Remedial Implementation Plan
SAC	Strategic Air Command
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act
SVOC	Semivolatile organic compound
TCA	Trichloroethane
TCE	Trichloroethene
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
US	United States
USC	United States Code
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile organic compound

SECTION 1
INTRODUCTION

Parsons Engineering Science, Inc. (Parsons ES) [formerly Engineering-Science, Inc. (ES)] was retained by the United States (US) Air Force Center for Environmental Excellence (AFCEE) to prepare a Phase III Remedial Action Plan (RAP) and a partial Phase IV Remedy Implementation Plan (RIP), pursuant to Title 310 of the Code of Massachusetts Regulations Section 40.0000 (310 CMR 40.0000), the Massachusetts Contingency Plan (MCP), for Landfill B (Site LF-01; Disposal Site Number 1-0000054) at Westover Air Reserve Base (ARB) in Chicopee, Massachusetts. The Phase III RAP/Phase IV RIP for Landfill B also will meet the substantive requirements of a Corrective Action Alternatives Analysis (CAAA) for a solid waste management facility, pursuant to 310 CMR 19.000. A Phase III RAP/Phase IV RIP was deemed necessary to support the selection and implementation of an alternative closure approach for the landfill, including natural attenuation for destruction and containment of groundwater contaminants and a modified cover system design that differs from the minimum design specifications set forth in 310 CMR 19.112 for Landfill B.

This work plan describes the additional site characterization data that must be collected to support a supplemental Phase III evaluation and preparation of the Phase III RAP/Phase IV RIP for Landfill B at Westover ARB. Emphasis has been given to identifying data required to demonstrate that an alternative closure approach, including a modified cover system design, will provide an "equivalent" level of protection to surface water and groundwater resources when compared to a standard closure approach (310 CMR 19.113). Because Landfill B has been classified by the Massachusetts Department of Environmental Protection (MADEP) as a Tier IA disposal

site, the Air Force, in accordance with 310 CMR 40.0550 and Transition Statement No. 78717, submits this work plan for review and approval prior to undertaking the described activities.

1.1 PROJECT BACKGROUND AND OBJECTIVES

Landfill B is a 14-acre site at Westover ARB that was used for domestic and general refuse disposal from 1960 until 1974. Refuse that may have been placed in Landfill B include drums from industrial operations. These drums may have contained paint residues, thinners, strippers, and other cleaning compounds such as methyl ethyl ketone (MEK), various chlorinated solvents, and dichlorobenzene (DCB). Several environmental investigations have been performed at Landfill B under the Air Force Installation Restoration Program (IRP) by the Air Force/Department of Defense, which have lead agency status pursuant to Section 10 of the United States Code Part 2701 (10 USC 2701) *et seq.* and 42 USC 9620. The Air Force IRP conforms with the US Environmental Protection Agency's (USEPA's) standard remedial investigation (RI)/feasibility study (FS) process. In 1988, a Phase II report detailing the outcome of a Phase I initial site assessment and Phase II evaluation was completed (ES, 1988). Based on this information, a final RI report, which included a quantitative baseline risk assessment (BRA), was prepared under the IRP in 1991 (Chem-Nuclear GeoTech, Inc. (Geotech), 1991). Subsequent to these reports, additional groundwater quality characterization activities were completed (Environmental Compliance Services, Inc. (ECS), 1993).

These historical reports were recently updated in a Phase II supplemental RI technical report (O'Brien & Gere Engineers, Inc. (OBG), 1996a). The updated Phase II RI presents all site characterization data collected since 1994, and reflects the 1993 revisions to the MCP, as promulgated by MADEP. A soil and groundwater sampling and analysis program was completed in 1994 to assess subsurface conditions at and around Landfill B. Additional surface soil, surface water, groundwater, sediment, and landfill gas sampling was performed in 1996 to further characterize the nature and

extent of potential contaminants at the site and to reassess potential chemical risks posed by this contamination. Concentrations slightly above laboratory reporting limits of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and pesticides were detected in surface soil samples. Several VOCs, primarily chlorinated solvents and breakdown products, were detected in groundwater underlying and immediately downgradient from Landfill B. VOCs also were detected in surface water and sediment samples collected from the drainage swale at the south side of the landfill. Chlorinated pesticides also were detected in a sediment sample from this location.

Moreover, the Phase II supplemental RI technical report (OBG, 1996a) updates the BRA completed as part of earlier IRP evaluations. The revised risk assessment indicates that unacceptable safety (i.e., fire or explosion) threats to onsite base maintenance workers may be present due to the presence of methane detected above its lower explosive limit (LEL). Based on the exposure scenarios evaluated in the updated BRA, no unacceptable risk due to exposure to residual chemical contamination was identified for current or anticipated future receptors. However, the 1996 Phase II supplemental RI did note that measured concentrations of several chemicals exceeded MADEP-defined groundwater standards. Additionally, the 1996 Phase II supplemental RI recommended that a Stage II Environmental Risk Characterization be completed to evaluate potential risks associated with environmental receptor exposures to site-related chemicals measured in surface soils, surface water, and sediments.

A Phase III FS was prepared concurrently with the Phase II supplemental RI (OBG, 1996b). The objective of the Phase III FS was to identify and recommend the most cost-effective remedial/closure approach for Landfill B based on available site characterization data and a comparative analysis of potential remedial/closure technologies. The recommended remedial/closure approach presented in the 1996 Phase III FS includes construction of an improved but alternate design cover system to minimize infiltration of precipitation through buried refuse, interrupt potential direct receptor exposure pathways from soil and buried refuse, and address potential nuisance

and aesthetic concerns. The proposed remedial/closure approach presented in the Phase III FS also specifies natural chemical attenuation of contaminants in groundwater. This combined approach meets the definition of a temporary solution, per 310 CMR 40.1000, with the potential for achieving a permanent solution. Several Activity and Use Limitations (AULs) will be required as part of this approach to minimize site access and prohibit use of groundwater in the immediate vicinity of the landfill.

Consequently, a Phase III RAP/Phase IV RIP was deemed necessary to:

- Support selection, approval, and conceptual design of an alternate cover design system that provides an "equivalent" level of protection as a standard approach, pursuant to 310 CMR 19.113;

- Demonstrate quantitatively that natural chemical attenuation processes are expected to be sufficient to contain, and possibly destroy/detoxify, groundwater contamination so that an alternate groundwater protection system may be selected and approved, contingent upon satisfying the requirements of an applicable Remedial Action Outcome (RAO), at least outside the boundary of the landfill;

- Evaluate and select the most cost-effective remedial/closure option for addressing any potentially unacceptable risks associated with landfill gases (e.g., methane) and surface water and sediment contamination;

- Assess the potential for ecological receptor exposure to site-specific chemical contamination; and

- Establish preliminary design criteria for closure/post-closure implementation plans, pursuant to 310 CMR 19.140(4), including a description of proposed post-closure maintenance, monitoring, and assessment activities.

To meet these objectives, additional site characterization data on potential chemical sources within the landfill and the nature and extent of contamination in soil gas,

groundwater, surface water, and sediments will be required. This work plan clearly identifies data needs in the context of preparing a Phase III RAP/Phase IV RIP. Available site characterization data will be used to the greatest extent possible to minimize duplication of effort.

1.2 WORK PLAN ORGANIZATION

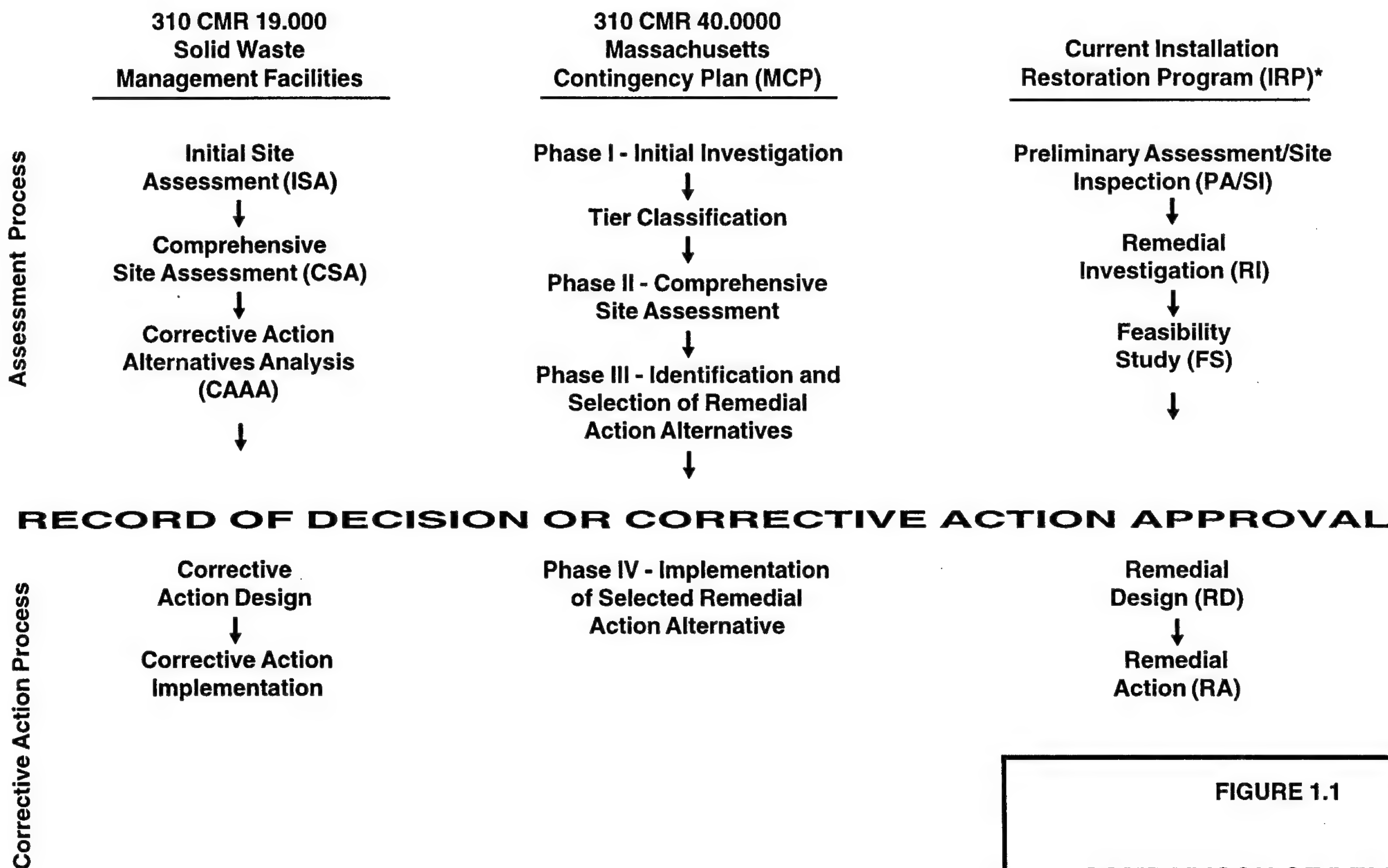
This work plan consists of eight sections, including this introduction, and two appendices. An overview of pertinent regulations and guidance that will be considered during field activities and preparation of the Phase III RAP/Phase IV RIP, as well as a summary of the scope of work and planned oversight activities, is presented in the remainder of this section. A review of site background, physical conditions, and previous site environmental investigations; a screening assessment to identify chemicals of potential concern (COPCs); and a description of the nature and extent of COPCs in impacted environmental media at Landfill B are included in Section 2. Section 3 summarizes the conceptual site model and other potential methods/models to be used to assess the short- and long-term effectiveness of potential remedial/closure approaches at Landfill B. Section 4 describes in detail the additional site characterization activities to be completed at Landfill B in support of the Phase III RAP/Phase IV RIP. The basic approach and methodology to be used to compare potential remedial/closure approaches in the Phase III RAP are outlined in Section 5. Section 6 identifies the elements of a Phase IV RIP that will be completed as part of this activity. Section 7 presents a preliminary schedule for completing the currently proposed activities, and Section 8 presents references used in preparing this work plan. A site sampling and analysis plan (SAP), which also specifies quality assurance/quality control (QA/QC) procedures, is included as Appendix A. A site health and safety plan (HASP) is included in Appendix B. Both the SAP and the HASP will be followed during the performance of additional site characterization activities described herein.

1.3 REGULATORY FRAMEWORK

There are three primary compliance programs that will be considered while conducting the activities described in this work plan. As presented in Figure 1.1, the major steps in each of these three programs are functionally equivalent. However, specific requirements that may be unique to one program (or incorporated by reference) will have to be identified to ensure that closure planning activities comply with all relevant regulations and guidance. Subsequent discussions briefly identify the major elements of these three compliance programs.

The first compliance program is for solid waste management facilities, which is set forth in 310 CMR 19.000. This program is intended to protect public health, safety, and the environment by comprehensively regulating the storage, transfer, processing, treatment, disposal, use, and reuse of solid waste in Massachusetts. Prior to landfill closure under this program, an assessment is required to determine and evaluate the extent of any adverse impacts of the landfill on the environment as a result of construction or operation (310 CMR 19.140(3)). The assessment process has been subdivided into three distinct phases: Initial Site Assessment (ISA), Comprehensive Site Assessment (CSA), and CAAA. In general, the assessment process involves compiling site history; characterizing the subsurface; determining potential rates and pathways of contaminant migration; identifying potential sensitive receptors; and determining air, groundwater, and surface water quality. The ISA consists of an historical literature review, a screening-level risk evaluation of existing data, and the identification of sensitive receptors. MADEP has provided comprehensive guidance on how to perform an ISA. The substantive requirements of an ISA were completed in 1987 as part of IRP activities (ES, 1988).

The second phase of the assessment process under 310 CMR 19.000 is a CSA. In addition to fully characterizing the nature and extent of chemical contamination, the CSA phase includes conducting a BRA to identify and evaluate potential health risks resulting from the landfill. A quantitative BRA may not be necessary as part of a CSA,



* Note that prior to 1986, IRP studies were organized in four phases; the IRP process now complies with CERCLA as amended by SARA.

FIGURE 1.1

COMPARISON OF RELEVANT REGULATORY PROGRAMS

Landfill B Phase III RAP/Phase IV RIP Work Plan
Westover ARB, Massachusetts

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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depending on the outcome of an initial, qualitative risk assessment. The qualitative risk assessment is basically a screening for completed receptor exposure pathways based on available site data. A quantitative risk assessment need only be undertaken if significant contamination is present and likely to threaten receptors, or if an alternative closure option is desired. MADEP recommends following USEPA risk assessment guidance if a quantitative risk assessment is necessary or desirable. As for an ISA, MADEP has provided detailed guidance on what is required to complete a CSA, including report preparation. The substantive requirements of a CSA pursuant to 310 CMR 19.150 and related MADEP guidance have been completed as part of the IRP (ES, 1988; Chem-Nuclear GeoTech, 1991; ECS, 1993; OBG, 1996a and 1996b).

The purpose of the third phase of the assessment process, the CAAA, is to analyze options for corrective actions to eliminate or mitigate the potential adverse impact caused by conditions at the facility, and to complete final closure in accordance with 310 CMR 19.140 and MADEP (1993) guidance. The CAAA also provides an opportunity to evaluate alternative options for securing closure of a landfill. The CAAA may be used to identify a closure approach that is less costly than the standard closure approach specified in 310 CMR 19.140, but equally as protective. In general, an alternative closure approach is most appropriate when no human or environmental receptors exist that may be affected by the landfill. Although only limited specific guidance on this phase has been developed by MADEP (1993), the CAAA report should identify corrective action objectives; list appropriate remedial/closure technologies; integrate these technologies into at least two closure approach "packages;" comparatively evaluate these closure approach "packages" in terms of their environmental benefit and economic impact; and finally, provide detailed justification for any recommended closure approach. Many of the elements of the CAAA have been completed in the Phase III FS (OBG, 1996b). However, in order to support selection of an alternative cover design system and to rely on natural chemical attenuation processes to contain groundwater contamination, the 1996 Phase III FS will have to be supplemented. Consequently, the Phase III RAP/Phase IV RIP will be

written to satisfy all of the requirements of a CAAA and most of the requirements of a final closure/post-closure plan (310 CMR 19.140(4)). This approach is more fully described in Section 5 of this work plan.

The second compliance program that must be considered when establishing remedial/closure plans for Landfill B is the MCP, which is set forth at 310 CMR 40.0000 pursuant to Massachusetts General Law (MGL) c.21 E, s.3 and s.6. The MCP is intended to provide for the protection of health, safety, public welfare, and the environment by establishing requirements and procedures for:

- Preventing/controlling chemical releases;
- Notification;
- Assessments;
- Remedial alternatives evaluations; and
- Public involvement.

The MCP is intended to comport with and complement the National Contingency Plan (NCP) promulgated by the USEPA under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The MCP applies if any response actions are being considered at a site, even if that site is already under the jurisdiction of another MADEP program. In general, response and closure actions performed at solid waste management facilities pursuant to 310 CMR 19.000 are sufficient to comply with the substantive requirements of 310 CMR 40.0000 (i.e., the MCP), provided such actions satisfy several conditions set forth at 310 CMR 40.0114. Two notable compliance exclusions include the requirement for a licensed site professional (LSP) opinion (310 CMR 40.0015) and the general requirements for conducting response actions set forth at 310 CMR 40.0190. This has been interpreted to mean that 310 CMR

19.000 and related MADEP (1993) guidance should be used to define the substantive requirements for assessment/closure activities, but that the general requirements of the MCP can provide an "umbrella" regulatory framework.

The "umbrella" regulatory framework of the MCP meshes well with the specific requirements of 310 CMR 19.000, particularly in terms of data evaluation and documentation requirements (see Figure 1.1). For example, similar to the solid waste management facility regulations, the MCP sets forth a phased approach for conducting response actions at disposal sites. Up to five different phases can be completed in accordance with the MCP. Phase I is an initial site investigation, similar to an ISA. Phase II is a comprehensive site investigation, similar to a CSA. Phase III involves identification and selection of comprehensive remedial action alternatives, similar to a Corrective Action Alternatives Analysis. Phase IV is designed to develop engineering concepts and design criteria for implementing the remedial action alternative selected under Phase III. The final phase, Phase V, sets forth any long-term compliance requirements, such as operation, maintenance, and monitoring commitments.

Previous environmental investigations completed for Landfill B have adopted the terminology and the basic substantive requirements of the MCP assessment process (e.g., Phase III FS). For example, the most recent Phase III FS report (OBG, 1996b) was intended to describe the outcome of a Phase III evaluation, as described in 310 CMR 40.0861. The stated purpose of a Phase III report, usually defined as a RAP, is to describe the applicable RAO and evaluate whether a temporary or permanent solution is feasible or can be implemented to achieve that Remedial Action Outcome. A RAO is essentially a qualitative description of cleanup objectives and requirements (310 CMR 40.1000). Although 310 CMR 19.000 does not specifically require that an RAO be established as part of the remedial/closure planning process, 310 CMR 40.0114 implies that the substantive requirements of establishing a RAO as part of the Phase III evaluation process is required for solid waste management facilities.

However, preparation of an RAO Statement, as described at 310 CMR 40.1056, is not required as part of landfill remedial/closure planning activities.

The 1996 Phase III FS indicates that at least one Activity and Use Limitation, in combination with the proposed remedial/closure activities, will be required to maintain a level of No Significant Risk at and downgradient from the landfill (OBG, 1996b). Consequently, because the finding of No Significant Risk apparently hinges on limiting potential exposures by AULs, the most recent remedial planning documents (i.e., the Phase II supplemental RI and the Phase III FS) imply that a Class B-2 RAO may be achievable at Landfill B. According to 310 CMR 40.1046(2), a Class B-2 RAO applies at sites where remedial actions have not been conducted because a level of No Significant Risk exists, but such a level is contingent upon one or more AULs that have been implemented at the site to restrict receptor exposures. The adequacy of this RAO will be presumed for purposes of identifying additional data requirements in this work plan.

In addition to developing a Phase III RAP that satisfies the substantive requirements of a CAAA, the Air Force intends to prepare a partial Phase IV RIP, as defined at 310 CMR 40.0850, as part of the work described herein. The primary purpose of a Phase IV RIP is to document engineering concepts and design criteria to be used for the design and construction of the selected corrective action/closure approach. Consequently, this information also should satisfy some of the requirements of a final closure/post-closure plan, as defined at 310 CMR 19.140(4). This work plan is not intended to describe all the activities to be completed for a Phase IV RIP or final closure/post-closure plans, as many of the Phase IV requirements must first be determined and approved in a Phase III RAP. Rather, the combined Phase II RAP/Phase IV RIP will include sufficient information to:

- Identify the goal(s) of the preferred corrective action/closure approach;

- Estimate the necessary effectiveness (i.e., design criteria) of various corrective action approaches, such as natural chemical attenuation rates, to achieve at least a Class B-2 RAO; and
- Conceptually describe the basic requirements, activities, and processes to be used to implement the selected remedial action alternative, including cover design specifications and long-term maintenance and monitoring activities.

The work to be completed as part of this effort does not include, at this point, preparation of detailed construction plans and specifications, or detailed maintenance, monitoring, and/or assessment plans. The basic elements of the Phase IV RIP to be completed as part of this effort are more fully described in Section 6 of this work plan.

The third and final compliance program that may need to be considered during completion of these activities is the Air Force IRP process. To date, all documentation prepared for Landfill B has been developed in response to ongoing IRP activities. The IRP remedial response action process complies with the requirements of CERCLA, as amended by the SARA. As presented in Figure 1.1, the IRP remedial response action process includes both an assessment phase and a corrective action phase. The 1996 Phase II RI and Phase III FS (OBG, 1996a and 1996b) were prepared in accordance with existing Air Force IRP (1993) guidance. These documents also include sufficient information to satisfy the documentation requirements of the National Environmental Policy Act (NEPA). Although the IRP process will be considered during activities proposed in this work plan, the requirements of 310 CMR 19.000 and 310 CMR 40.0000 will have primacy.

1.4 SCOPE OF WORK

As the preceding discussions indicate, there are two primary areas where additional data are needed to support the preparation of the proposed Phase III RAP and a partial Phase IV RIP. The first area includes collecting adequate data to fully characterize the nature and extent of chemical contamination at Landfill B, with particular emphasis on

establishing the potential for long-term chemical sources and quantitatively evaluating chemical fate and transport mechanisms. This information will be critical in demonstrating that an "equivalent" level of protection is provided by alternate cover and groundwater protection system designs. Data on the presence of explosive or malodorous landfill gases also are necessary to conceptually design a long-term landfill cover system. Additionally, data relevant to estimating potential ecological receptor exposures to chemical contaminants in surface soil, surface water, and sediments are necessary. The second area includes collecting sufficient data to establish applicable RAOs for Landfill B. This effort may include revising existing risk estimates to evaluate the need for AULs and to establish design and validation criteria for assessing the effectiveness of natural chemical attenuation processes.

1.4.1 Confirmation of Contaminant Distribution

The main objective of the additional site characterization activities described in Section 4 of this work plan is to confirm the nature and extent of contamination in environmental media underlying and immediately downgradient from the landfill. This work plan prescribes collection of soil gas samples and groundwater samples from temporary sampling locations to fully define the nature of potential chemical sources and to establish a perimeter of environmental contamination at the site. A biased sampling approach will be pursued to identify potential sources or "hot spots." These data are important in demonstrating that alternate cover and groundwater protection system designs provide a level of protection "equivalent" to that offered by a more standard closure approach. Additionally, sampling data are required to quantitatively evaluate the potential for natural chemical attenuation processes to contain groundwater contamination, and possibly destroy/detoxify contamination over time. These data are equally important in establishing whether the remedial/closure approach conceptually presented in the Phase III FS (OBG, 1996b) is sufficient to minimize leachate generation, minimize impacts on receiving surface waters, and establish appropriate surface water controls and/or monitoring plans. Data from previous environmental

investigations are presented in Section 2 to focus the types of sampling activities required to meet the requirements described above.

1.4.2 Estimating Potential Risks to Human Health and the Environment

Additional data relevant to revising and upgrading existing risk estimates and establishing appropriate RAOs also are proposed in this work plan. Two basic risk characterization approaches will be pursued as part of this effort. First, a chemical-specific approach that involves comparing measured site concentrations to established standards will be used to identify COPCs and perform a screening-level risk evaluation. Second, a cumulative risk approach, which may include developing probabilistic risk estimates, will be completed to determine whether a specific remedial/closure approach is necessary and protective and to select the appropriate RAO for the site pursuant to 310 CMR 40.1000. The target cumulative carcinogenic risk level for this type of risk characterization activity will be 1×10^{-5}. Additionally, data relevant to assessing the potential for ecological receptor exposure to contaminated soil, surface water, and sediment will be collected and considered as part of this effort. Such information is required to supplement the human health risk estimates that have been presented previously (Geotech, 1991; OBG, 1996a) to ensure that any recommended remedial/closure approach also is protective of environmental resources.

1.5 LICENSED SITE PROFESSIONAL (LSP) OVERSIGHT

All work, data evaluation, and reports prepared as part of this effort will be completed by competent professionals experienced in relevant technical areas under the supervision of a registered professional engineer (310 CMR 19.011(2)). Additionally, although not specifically required by 310 CMR 19.000, a licensed site professional (LSP) will provide technical oversight, as necessary, to meet the requirements of 310 CMR 40.0000. The LSP-of-Record for this effort will be Mr. Robert Kane (Massachusetts State LSP Registration Number 4333). He is currently in the employ of the Parsons ES Boston office.

SECTION 2

REVIEW OF AVAILABLE SITE DATA

Site hydrogeologic characteristics and the known nature and extent of contamination at Landfill B were preliminarily established from data collected during previous investigations (ES, 1988; Geotech, 1991; ECS, 1993; OBG, 1996a). Available site data were reviewed to identify additional site characterization activities that need to be completed to prepare a Phase III RAP and a partial Phase IV RIP that satisfies 310 CMR 19.000 and 310 CMR 40.0000. As noted in Section 1, these data will be used to supplement existing characterization data to establish RAOs, quantitatively compare different remedial/closure approaches, and justify selection of an alternate cover and groundwater protection system design and closure approach, if appropriate.

2.1 SITE BACKGROUND

Westover ARB is located in Hampden County in south-central Massachusetts. The base covers approximately 2,400 acres in the northeastern portion of the city of Chicopee within the Connecticut River Valley, and is approximately 90 miles west of Boston (Figure 2.1). The base became operational in April 1940, and served as a training center for the 359th Fighter Group until 1945. During the period from 1945 to 1974, the base served the Military Air Transport Services and the Strategic Air Command (SAC). The Air Force Reserve came to Westover in 1965, and in 1974 the base was deactivated to become an Air Force Reserve base. Currently the base is the nation's largest Air Force Reserve base and is operated by a work force of 1,200 civilians, including 533 Air Reserve technicians. Over 4,000 reservists from all military branches throughout the northeastern US serve at Westover ARB.

Site LF-01 (Landfill B) is located on approximately 14 acres in the northwestern corner of the base (Figure 2.1). The landfill was operated from 1960 until 1974 as a disposal area for domestic and general base refuse. The refuse included 55-gallon drums and empty containers used in base industrial operations (ES, 1988). The landfill may have received leaded fuel filters and leaded sludge removed from the bottoms of fuel tanks (ES, 1988). Additional landfilled waste from industrial operations may have included paint residues, thinners, stripers and aircraft cleaning compounds (OBG, 1996a). At the conclusion of disposal activities, a silty, fine sand cover with a maximum thickness of 2 feet was placed over the landfill. The site is currently surrounded by open space and a small arms firing range located on the eastern boundary of the landfill (Figure 2.2).

2.1.1 Previous Investigations at Landfill B

As summarized in Section 1, several environmental investigations have been conducted at Landfill B. The initial site assessment was conducted under the IRP in 1987 (ES, 1988). ES performed an electrical resistivity (ER) survey, installed monitoring wells B-1 through B-10, and collected three rounds of groundwater, surface water, and sediment samples. All collected samples were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX), other VOCs, SVOCs, common anions, and metals. Geotech (1991) conducted aquifer hydraulic tests and collected groundwater, surface water, and sediment samples for VOC, SVOC, anions, and metals analysis. Environmental Compliance Services (1993) installed two groundwater monitoring well pairs (B-13, B-13A, and B-14, B-14A) downgradient from the landfill perimeter. Groundwater samples from these newly installed wells were analyzed for VOCs and total petroleum hydrocarbons (TPH).

OBG collected additional site characterization data in 1994 and 1996 to supplement available IRP RI data. Groundwater elevation data and groundwater quality data for 16 monitoring wells for VOC, SVOC, and metals analysis were collected in May 1994. A ground-penetrating radar (GPR) survey and excavation test pit program also were performed to locate the horizontal boundaries of the landfill, assess the depth of the fill material, and identify significant anomalies that may represent buried contaminants or

persistent chemical sources. Additional groundwater, surface water, sediment, surface soil, and landfill soil gas samples were collected in 1996 to support preparation of a supplemental RI report. Surface water and sediment samples were analyzed for VOCs, chlorinated pesticides, and metals. Surface soils also were analyzed for these parameters with the addition of SVOCs and herbicides. All groundwater samples were analyzed for VOCs, and upon request by MADEP, selected samples were analyzed for chlorinated pesticides and 1,4-dioxane. Laboratory landfill soil gas samples were analyzed for methane, oxygen, nitrogen, carbon dioxide, non-methane hydrocarbons, and VOCs. Field soil gas measurements included hydrogen sulfide, oxygen, carbon dioxide, methane, and total LEL. Information on detected concentrations of target analytes in affected site media is presented in Section 2.3 of this work plan.

2.2 PHYSICAL SETTING

2.2.1 Site Topography and Surface Hydrology

Westover ARB is located within the Connecticut River Valley Lowland Subdivision of the New England Upland Physiographic Province, which is part of the Northern Appalachian Mountain System. The predominant topographic features of the area are the nearly level flood plains, level to gently sloping terraces along the Connecticut River, and several large intrusive dikes that rise several hundred feet above the valley floor (ES, 1988). Regional elevations range from 50 feet above mean sea level (msl) at the Connecticut River to 1,200 feet msl to the north of the base at the summit of Mount Tom. Elevations at the Landfill B site range from approximately 240 to 245 feet above msl, and the surface grade is essentially level with the exception of mounds and depressions associated with the waste piles.

The base is located approximately 2 miles east of the Connecticut River and is drained by three smaller drainages: Stony Brook to the north, Willamansett Brook to the west, and Cooley Brook along the southeastern boundary of the base (Figure 2.1). Langewald Pond and Mountain Lake, west of the base, receive water from Willamansett Brook. Cooley Brook receives runoff from most of the base industrial operations, flight line

hangars, and runways via storm sewers, culverts, and ditches. Cooley Brook supplies water to Chicopee Reservoir and the Chicopee River (approximately 1 mile south of the base).

Stony Brook, which is located approximately 2,000 feet east of the site, receives runoff from Landfill B and the northern portion of the base, mainly through storm drains that outfall at the brook south and east of Landfill A (OBG, 1993). A drainage swale is located on the south side of the landfill and receives surface water flow from the landfill. Surface water in the swale flows to the south where it drains into a system of storm drains that discharge into Stony Brook (ES, 1988).

2.2.2 Overview of Geology and Hydrogeology

2.2.2.1 Regional Geology and Hydrogeology

The central Massachusetts bedrock geology consists of a variety of Precambrian and early Paleozoic crystalline rocks known as the Grenville crystallines (ES, 1988). These rocks are most evident as the Adirondack Mountains to the west of the base. The crystalline rocks underwent periods of folding, faulting, metamorphism, and intrusion during the Taconic (Ordovician) and Acadian (Devonian) orogenies. The resulting stresses from these orogenies produced extensive folding and faulting during the Paleozoic Era. Additional folding and rifting occurred in the early Jurassic period, and a series of north/south-trending fault structures were formed. Unconformably overlying the crystallines are Triassic "redbeds" consisting of arkosic sandstone, conglomerates, siltstones, and occasional gray shales. The Triassic rocks in the Westover ARB area are reddish-brown arkosic sand and siltstones of the Portland Formation. Uplift and erosion of the Triassic formations resulted in an unconformity between the Portland Formation and overlying Pleistocene glacial sediments.

The Pleistocene glacial advance reshaped the landscape and deposited poorly sorted gravel, sand, silt, and clay mixtures as moraines and till sheets. During the glacial retreat, meltwaters impounded by glacial deposits and present topography formed several large

glacial lakes. The largest of the Pleistocene lakes in the region was glacial Lake Hitchcock, which extended from Hartford, Connecticut to Lyme, New Hampshire. The lake was as much as 250 feet deep in the Chicopee area (Thomas, 1987). The resulting sedimentation deposited thick, gray, varved lacustrine clays with silt and fine sand laminations. Overlying the lacustrine sediments are brown to gray, fine to coarse sands with traces of gravel and silt. These sediments are deltaic outwash deposits that formed as glacial Lake Hitchcock drained and filled with sediment.

The regional hydrogeology of the Westover ARB area consists of three major hydrogeologic units. An aquitard composed of lacustrine deposits and till separates the shallow deltaic outwash aquifer from the underlying Triassic bedrock aquifer. Both aquifers are used to a limited extent for industrial, municipal, and domestic purposes (OBG, 1993). Because of the thick aquitard, it is considered unlikely that site-related contaminants in the shallow aquifer could adversely impact the Triassic bedrock aquifer. The glacial outwash aquifer ranges in thickness from 25 to 85 feet in the area of the base, and is recharged by infiltration and runoff from rain and melting snow (OBG, 1993). Depth to shallow groundwater is generally 5 to 40 feet below ground surface (bgs), and is influenced by surface topographic features. The hydraulic conductivity for silty sands and clean sands typical of outwash deposits ranges from 0.03 to 2,800 feet per day (ft/day) (Freeze and Cherry, 1979). Results from pump tests performed by Geotech (1991) indicated that the hydraulic conductivities at the base averages 13 ft/day and ranges from 2.2 to 33 ft/day.

2.1.2.2 Landfill B Geology and Hydrogeology

The current landfill cover material, which ranges from a few inches to 2 feet thick, consists of a native fine sand. The landfill material is primarily a mixture of paper, plastic, glass, wood, and metal debris. The average fill thickness is approximately 5 to 6 feet, and is mixed with native sandy material with a strong odor of decaying garbage (OBG, 1996a). On the basis of the GPR survey, the depth of the fill averaged 8 to 10 feet bgs, with an estimated maximum depth of 12 feet bgs near the center of the landfill. The GPR and test

pit surveys indicated uniform fill material with no indications of full waste containers or pools of nonaqueous liquid contamination (OBG, 1996a).

Underlying the landfill material and in undisturbed portions of the site, the sediments at Landfill B consist primarily of fine- to coarse-grained sands and gravels, overlying varved fine sand, silt, and clay lacustrine deposits. Sediments above the lacustrine deposits coarsen upward, as is typical of a deltaic depositional environment. Sands are loose to medium dense, tan to brown, and very fine to coarse grained. Within the coarse sands, gravel-sized material is also present. Environmental Compliance Services (1993) reported that a medium dense, fine to coarse sand and gravel layer underlies the landfill material at Landfill B to a depth of 25 feet bgs. Approximately 20 to 30 feet of fine sand and fine silty sand underlie this sand and gravel layer. Environmental Compliance Services (1993) also reported a fine to coarse sand interbedded with the fine sand layer between 45 and 50 feet bgs in soil borehole B-16. Underlying the fine sand, a varved silt, clay, and sand lacustrine deposit is present to approximately 100 feet bgs. Underlying the lacustrine deposit are the till and arkosic sandstone bedrock units (ES, 1988).

The groundwater flow direction varies from southeast to east at the landfill site. Figure 2.3 is a groundwater surface map based on May 1996 groundwater elevation data (OBG, 1996a). These data are consistent with previous groundwater flow direction and gradient data. Overall, the depth to shallow groundwater at Landfill B is 5 to 10 feet bgs throughout the year. The hydraulic gradient in May 1996 was estimated at 0.004 to 0.012 foot per foot (ft/ft) in the upper portions of the deltaic outwash aquifer. The horizontal gradient increases eastward across the site toward Stony Brook. The relatively flat groundwater gradient beneath Landfill B can be attributed in part to the lack of influential topography. The increase in hydraulic gradient east of the site may be the result of the steeper topography. On the basis of May 1996 groundwater elevations at monitoring well clusters, the vertical gradient in the aquifer was found to range from 0.007 to 0.05 ft/ft and to average 0.03 ft/ft downward.

The hydraulic conductivity at Landfill B has been estimated to range from 3.2 to 33 ft/day (Geotech, 1991). In the shallow portions of the aquifer, the average hydraulic conductivity is estimated at 21 ft/day, while in the deeper zones of the aquifer, the average hydraulic conductivity is 16 ft/day. Calculated groundwater flow velocities at the site, using an effective porosity of 0.25, range from 0.34 to 1.0 ft/day.

2.3 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

A screening-level comparison between maximum measured chemical-specific site analytical data and applicable MADEP screening levels or, in the absence of MADEP standards, USEPA screening levels is presented in this section. The purpose of this screening assessment is to focus subsequent data evaluation and additional site characterization activities on those chemicals that may drive the scope and nature of the required remedial/closure approach. Where Method 1 standards are available, they were used without site-specific modification. In the absence of Method 1 standards, alternate criteria were selected based on the Method 1 standard assumptions.

Method 1 standards have been promulgated by MADEP for both soil and groundwater assuming three different types of exposure. Because the applicable classification of soil and groundwater may depend on AULs to be in place as part of the remedial/closure approach, the objective of this screening-level assessment is not to classify media in accordance with 310 CMR 40.0930 or characterize potential risks in accordance with 310 CMR 40.0902(5). Rather, the goal of this screening-level assessment is to identify those chemicals that may need to be considered in the risk characterization effort conducted as part of the Phase III evaluation process. This screening assessment is similar but not identical to that presented in the Phase II supplemental RI (OBG, 1996a). All data collected to date at the Landfill B were used to establish COPCs.

Groundwater underlying and immediately downgradient from Landfill B has been re-classified as Groundwater Category GW-2 (Moriarity, 1996). However, due to the presence of potable wells immediately off-base to the northwest of the landfill, GW-1 standards (i.e., potable water standards) are considered appropriate as screening criteria

for groundwater that may be migrating off base. Therefore, to identify those contaminants that may drive the need for groundwater AULs (or even a classification of GW-2), the screening-level assessment presented herein consists of a comparison of detected concentrations of groundwater contaminants to GW-1 standards (310 CMR 40.0974(2)). If no GW-1 standard has been promulgated by MADEP for a detected compound, the conservative residential-use risk-based concentrations (RBCs) developed for groundwater by USEPA Region III (1996) were used as comparison criteria. These groundwater RBCs assume the groundwater is used as a potable source of water, which is similar to the exposure assumptions underlying the derivation of the GW-1 standards. Note that exceedances of these preliminary screening criteria should not be interpreted to contradict the finding of No Significant Risk presented in the Phase II supplemental RI (OBG, 1996a) or Phase III FS (OBG, 1996b). The most recently measured maximum detected groundwater concentrations are compared against the screening-level Method 2 standards in Table 2.1 Chemicals measured during at least one recent sampling event at concentrations above these conservative comparison criteria are shaded and identified as groundwater COPCs for purposes of this work plan.

2.3.1 Soil COPCs

MADEP also has promulgated standards for three soil categories (310 CMR 40.40.0975(6)). Similar to groundwater classifications, soil classifications depend on the type and nature of exposures that could occur at a site. The applicable soil category also is a function of the groundwater category. Because the site will be closed in accordance with 310 CMR 19.140, the assumptions underlying the S-1 soil category are unrealistic (i.e., overly conservative) for this screening-level comparison. Specifically, category S-1 presumes that the soil could be used for growing fruits or vegetables, or that a child or adult could frequently come into direct contact with contaminated soil. Neither exposure assumption is reasonable for Landfill B. Consequently, soil category S-2 standards (310 CMR 40.0975(6)(b)) were used as comparison criteria for detected surface soil contaminants. Soil category S-2 standards assume that exposure of child receptors is low, but an adult receptor may have either a high frequency of contact with or high intensity of

TABLE 2.1
COMPARISON OF SITE GROUNDWATER CONTAMINANT CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP/PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Maximum Detected Site Concentration	MCP GW-1 Standard [a/]	Max. Conc. Exceeds MCP GW-1 Standard	Units
Benzene	49	5	Yes	µg/L [b/]
Toluene	760	1,000	No	µg/L
Ethylbenzene	220	700	No	µg/L
Xylenes (Total)	210	10,000	No	µg/L
Naphthalene	24	20	Yes	µg/L
Chloroethane	670	8,600 [c/]	No	µg/L
Acetone	26	3,000	No	µg/L
Chlorobenzene	44	100	No	µg/L
1,1-Dichloroethane	1,900	70	Yes	µg/L
1,2-Dichloroethane	3.7	5	No	µg/L
cis-1,2-Dichloroethene	2.1	70	No	µg/L
1,1-Dichloroethene	5.1	7	No	µg/L
Vinyl Chloride	23	2	Yes [d/]	µg/L
trans-1,3-Dichloroethane	4.5	NA [e/]	NA	µg/L
bis (2-Ethylhexyl)phthalate	110	6	Yes	µg/L
2,4-Dimethylphenol	20,000	100	Yes	µg/L
2-Methylnaphtha	55	NA	NA	µg/L
Methylene Chloride	17 J	5	Yes	µg/L
2-Chlorophenol	480	10	Yes	µg/L
2,4-Dichlorophenol	240	10	Yes	µg/L
Phenol	220	4,000	No	µg/L
2,4,6-Trichlorophenol	320	10	Yes	µg/L
2,4-Dinitrophenol	850	200	Yes	µg/L
2-Nitrophenol	2,000	NA	NA	µg/L
P-chloro-m-cresol	650	NA	NA	µg/L
Pentachlorophenol	17	1	Yes	µg/L
4,6-Dinitro-o-cresol	5.5	500	No	µg/L
Tetrachloroethene	3.3	5	No	µg/L
1,1,2,2-Tetrachloroethane	1.4	2	No	µg/L
1,1,1-Trichloroethane	570	200	Yes	µg/L
1,1,2-Trichloroethane	14	5	Yes	µg/L
Isopropylbenzene	3.8	NA	NA	µg/L
1,2-Dichlorobenzene	220	600	No	µg/L
1,3-Dichlorobenzene	1.6	600	No	µg/L
1,4-Dichlorobenzene	19	5	Yes	µg/L
Chloroform	11 J	5	Yes	µg/L
n-propylbenzene	0.61	NA	NA	µg/L
1,2,4-Trimethylbenzene	22	300 [c/]	No	µg/L
1,3,5-Trimethylbenzene	2.1	300 [c/]	No	µg/L

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TABLE 2.1 (Concluded)
COMPARISON OF SITE GROUNDWATER CONTAMINANT CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP/PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Detected Site Maximum Concentration	MCP GW-1 Standard	Max. Conc. Exceeds MCP GW-1 Standard	Source
Heptachlorobenzene	0.02	0.4	No	µg/L
2-Methylnaphthalene	2.8	10	No	µg/L
Trans-1,3-Dichloropropane	0.5	0.5	No	µg/L
1,2-Dichloropropane	1.7	5	No	µg/L
Trans-1,2-Dichloropropene	0.2	NA	NA	µg/L
Bromodichloromethane	2.2	5	No	µg/L
Dibromochloromethane	0.4	5	No	µg/L
Dichlorodifluoromethane	1.2	390 [c/]	No	µg/L
Lindane	0.04	NA	NA	µg/L
Aluminum	4.2	37.0 [c/]	No	mg/L [f/]
Arsenic	0.050	0.050	No	mg/L
Barium	0.3	2.0	No	mg/L
Cadmium	0.01	0.005	Yes	mg/L
Calcium	47.6	NA	NA	mg/L
Chromium	0.08	0.1	No	mg/L
Cobalt	0.037	2.2 [c/]	No	mg/L
Copper	0.025	10.0	No	mg/L
Iron	174	11.0 [c/]	Yes	mg/L
Lead	0.120	0.015	Yes	mg/L
Magnesium	12.7	NA	NA	mg/L
Manganese	4.1	0.84 [c/]	Yes	mg/L
Molybdenum	0.031	0.18 [c/]	No	mg/L
Potassium	47.4	NA	NA	mg/L
Sodium	75.2	NA	NA	mg/L
Vanadium	0.05	0.05	No	mg/L
Zinc	1	2.00	No	mg/L

[a/] Source: MADEP (1993) Groundwater Catergory GW-1 Standards.

[b/] µg/L = micrograms per liter.

[c/] USEPA Region III (1996) residential ingestion risk-based concentration.

[d/] Vinyl chloride is the only chemical with a maximum concentration that also exceeds its GW-2 Standard of 2 ug/L.

[e/] NA = criterion not available.

[f/] mg/L = milligram per liter.

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exposure to contaminated soil. As with groundwater, USEPA Region III (1996) soil RBCs for industrial sites were used in absence of promulgated S-2 soil standards. Table 2.2 presents a comparison of maximum detected surface soil chemical concentration to these Method 2 soil comparison criteria. None of the chemical concentrations detected at the landfill exceed these conservative comparison criteria. Therefore, no soil COPCs have been identified for purposes of this work plan.

2.3.2 Soil Gas, Sediment, and Surface Water COPCs

In addition to groundwater and soil, chemicals have been detected in soil gas, sediment, and surface water. MADEP has not promulgated standards for these environmental media. However, to ensure that the full range of COPCs are identified as part of this work plan, comparison criteria for these environmental matrices were identified from other sources. The time-weighted average (TWA) permissible exposure limits (PELs) established by the Occupational Safety and Health Administration (OSHA) were used as industrial ambient air comparison criteria. Maximum detected soil gas concentrations are compared to the OSHA PELs in Table 2.3. The comparison between measured soil gas concentrations to OSHA PELs is conservative. Intuitively, soil gas measurements taken below ground surface will overestimate actual and potential ambient air concentrations. Only methane, detected in one soil gas sample, is identified as an air COPC in table 2.3. Methane was identified as an air COPC because it exceeds its LEL of 5,300 parts per million, volume per volume (ppmv) (i.e., represents a potential safety hazard).

Comparison criteria for sediment and surface water were identified from available USEPA and state guidance. The New York State Department of Environmental Conservation (1993) has developed technical guidance for screening contaminated sediments for the protection of aquatic benthic organisms and protection of humans from food chain impacts. These screening levels were developed by correlating measured concentrations of chemicals in sediments with the severity of its observed biological impact. Table 2.4 presents a comparison of detected sediment concentrations to these screening-level sediment comparison criteria. Again, the goal of this assessment is only to

TABLE 2.2
COMPARISON OF SITE SURFACE SOIL CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP/PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Maximum Detected Site Concentration	MADEP Soil Catagory S-2 Standard[a/]	Max Conc. Exceeds S-2 Standard
Hexachlorocyclopentadiene	0.37	14,000[c/]	No
Phenanthrene	0.041	700	No
Fluoranthene	0.063	600	No
Pyrene	0.061	500	No
Chrysene	0.043	10	No
bis(2-Ethylhexyl)Phthalate	0.97	100	No
Benzo(b)fluoranthene	0.065	1	No
Benzo(a)pyrene	0.043	0.7	No
4,4-'DDE	0.064	2	No
Dieldrin	0.002	0.04	No
4,4-'DDD	0.09	3	No
4,4-'DDT	0.19	2	No
Chlordane	0.035	2	No
Dinoseb	0.36	2,000[c/]	No
Antimony	1.0	40	No
Arsenic	1.4	30	No
Cadmium	1.2	80	No
Chromium	11.0	600	No
Copper	38.0	82,000[c/]	No
Lead	68.0	600	No
Mercury	0.2	60	No
Nickel	8.0	700	No
Selenium	0.6	2500	No
Silver	6.0	200	No
Zinc	92.0	2500	No

[a/] Source: MADEP, 1993.
[b/] mg/kg = milligrams per kilogram.
[c/] Source: USEPA Region III (1996) risk-based concentration for industrial soils.

TABLE 2.3
COMPARISON OF SITE SOIL GAS CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP/PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Maximum Detected Site Concentration (ppbv)[b/]	NIOSH TWA[a/] For Ambient Air (ppbv)	Max. Conc. Exceeds NIOSH TWA
Benzene	3.5	1,000	No
Toluene	6.5	100,000	No
Xylenes (Total)	26.0	100,000	No
Tetrachloroethene	9.1	25,000	No
Vinyl Chloride	15.0	1,000	No
Methane	2.40E+08	NA[c/]	--[d/]

[a/] Source: NIOSH, 1990. TWA = time weighted average.

[b/] ppbv = parts per billion, volume per volume.

[c/] NA = TWA not available.

[d/] 310 CMR 19.000 and MADEP (1993) specify an imminent methane gas hazard of 25 percent of the methane lower explosive limit (5300 ppbv).

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TABLE 2.4
COMPARISON OF SITE SEDIMENT CONTAMINANT CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP\PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Maximum Detected Site Concentration	Screening Criterion[a]	Maximum Concentration Exceeds Criterion	Units
Methylene Chloride	0.008	NA[b]	NA	mg/kg[c]
cis-1,2-Dichloroethane	0.014	0.7	No	mg/kg
Benzene	0.004	0.6[d]	No	mg/kg
Toluene	0.001	NA	NA	mg/kg
1,1-Dichloroethane	1.3	0.7	No	mg/kg
Dichloromethane	1.7	NA	NA	mg/kg
Chlorobenzene	1.3	3.5	No	mg/kg
1,2-Dichlorobenzene	8.8	12[d]	No	mg/kg
Heptachlor	0.002	0.0008[d] 0.1[e]	No	mg/kg
4,4-'DDE	0.082	0.01[d] 1.0[e]	No	mg/kg
4,4-'DDD	0.29	0.01[d] 1.0[e]	No	mg/kg
4,4-'DDT	0.02	0.01[e] 1.0[e]	No	mg/kg
Chlordane	0.011	0.001[d] 0.03[e]	No	mg/kg
Endrin ketone	0.003	0.8[d]	No	mg/kg
Arsenic	5.6	6.0[f]	No	mg/kg
Beryllium	0.8	NA	NA	mg/kg
Cadmium	0.7	0.6	Yes	mg/kg
Chromium	17.0	26	No	mg/kg
Copper	12.0	16	No	mg/kg
Lead	12.0	31	No	mg/kg
Selenium	2.0	NA	NA	mg/kg
Zinc	110.0	120	No	mg/kg

[a] Source: New York State Department of Environmental Conservation (1993) Technical Guidance for Screening Contaminated Sediments. Criteria for organic chemical are based on an assumed total organic carbon concentration of 1 percent.

[b] NA = criterion not available.

[c] mg/kg = milligrams per kilogram.

[d] Human health bioaccumulation screening criteria.

[e] Benthic aquatic life chronic toxicity screening critera.

[f] Lowest effect level.

identify media and chemicals that may need to be evaluated further as part of the Phase III evaluation.

Comparison criteria for surface water are based on USEPA (1991) water quality criteria. Both freshwater chronic aquatic organism and human health surface water quality criteria are included on Table 2.5. In cases where the groundwater comparison criteria (Table 2.1) were more stringent than the USEPA (1991) human health surface water quality criteria, the groundwater comparison criteria are used instead. Chemicals measured during the limited sediment and surface water quality sampling event at concentrations above these conservative comparison criteria are shaded and identified as sediment and/or surface water COPCs for purposes of this work plan.

2.3.3 Summary of Site COPCs

Table 2.6 summarizes the conclusions of this screening-level evaluation. COPCs for each environmental matrix are identified. Several VOCs, SVOCs, and metals were identified as groundwater COPCs. No soil COPCs were identified. Only methane is identified as a potential air COPC. Finally, several VOCs, pesticides, and metals were identified as sediment and/or surface water COPCs. The nature and extent of these COPCs is further described in subsequent discussions. This information is crucial to establish data needs for the Phase III RAP and partial Phase IV RIP.

2.4 NATURE AND EXTENT OF CONTAMINATION

The following sections summarize available sampling data on each of the COPCs identified for Landfill B.

2.4.1 Soil Gas Data

Soil gas samples were collected in 1996 at the Landfill B site from six locations at an approximate depth of 6 feet bgs (OBG, 1996a). The soil gas sampling locations and results for methane are presented on Figure 2.4. A soil gas sample was collected from

TABLE 2.5
COMPARISON OF SITE SURFACE WATER CONTAMINANT CONCENTRATIONS TO SCREENING CRITERIA
LANDFILL B PHASE III RAP/PHASE IV RIP WORK PLAN
WESTOVER ARB, MASSACHUSETTS

Detected Analytes	Maximum Detected Site Concentration	Ambient Water Quality Criterion Fresh Water Chronic[a/]	Max. Conc. Exceeds Ambient Criteria	Human Health RBC	Max. Conc. Exceeds Human Health RBC	Units
1,1-Dichloroethene	49	NA[b/]	NA	7.0 [c/]	Yes	µg/L
Trichloroethene	56	21900	No	2.7 [d/]	Yes	µg/L
Ethylbenzene	89	NA	NA	1400 [d/]	No	µg/L
Toluene	11	NA	NA	14300 [d/]	No	µg/L
Chloroethane	210	NA	NA	8600 [c/]	No	µg/L
Chlorobenzene	65	NA	NA	100 [c/]	No	µg/L
1,1-Dichloroethane	320	NA	NA	70 [c/]	Yes	µg/L
cis-1,2-Dichloroethene	24	NA	NA	70 [c/]	No	µg/L
Vinyl Chloride	70	NA	NA	2.0 [c/d/]	Yes	µg/L
Methylene Chloride	17	NA	NA	5.0 [c/]	Yes	µg/L
Tetrachloroethene	35	840	No	0.8 [d/]	Yes	µg/L
1,1,2,2-Tetrachloroethane	44	2400	No	0.17 [d/]	Yes	µg/L
1,1,1-Trichloroethane	17	NA	NA	200 [c/]	No	µg/L
1,2-Dichlorobenzene	64	NA	NA	600 [c/]	No	µg/L
1,4-Dichlorobenzene	14	NA	NA	5.0 [c/]	Yes	µg/L
Lindane	0.024	NA	NA	NA	NA	µg/L
4,4'-DDE	0.039	NA	NA	0.1 [c/]	No	µg/L
Dieldrin	0.055	0.0019	Yes	0.0014[d/]	Yes	µg/L
4,4'-DDD	0.068	NA	NA	0.1 [c/]	No	µg/L
Arsenic	15	850	No	0.018 [d/]	Yes	µg/L
Barium	100	NA	NA	1000 [d/]	No	µg/L
Cadmium	18	1.1	Yes	5.0 [c/]	Yes	µg/L
Iron	21000	1000	Yes	300 [d/]	Yes	µg/L
Lead	10	3.2	Yes	15 [c/]	No	µg/L
Manganese	3590	NA	NA	50 [d/]	Yes	µg/L
Zinc	440	110	Yes	2000 [c/]	No	µg/L

[a/] Source: USEPA (1991) water quality criteria to protect aquatic organsims in freshwater under chronic exposure conditions
[b/] NA = criterion not available.
[c/] USEPA (1991) Ingestion based criteria.
[d/] USEPA (1991) Criteria for Water and Organisms.

TABLE 2.6
SUMMARY OF COPCs
LANDFILL B PHASE III RAP/PHASE IV RIP WORKPLAN
WESTOVER ARB, MASSACHUSETTS

Chemicals of Potential Concern	Rationale [a/]
Sediment	
Cadmium	1996 concentration > New York State (1993) Technical Guidance for Screening Contaminated Sediments
Surface Water	
1,1-Dichloroethene	1988 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Trichloroethene	1996 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
1,1-Dichloroethane	1987 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Vinyl Chloride	1987 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Methylene Chloride	1987 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Tetrachloroethene	1987 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
1,1,2,2-Tetrachloroethane	1987 concentration and 1996 detection limit > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
1,4-Dichlorobenzene	1987 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Dieldrin	1996 concentration > USEPA 1991 Water Quality Human Health Risk Based Criteria for water and organisms
Groundwater	
1,1-Dichloroethane	1996 concentration > MCP GW-1 Standard
Vinyl Chloride	1988 concentration and 1996 detection limit > MCP GW-1 and GW-2 Standard
bis (2-Ethylhexyl)phthalate	Only analyzed in 1988 and concentration > MCP GW-1 Standard
Methylene Chloride	1996 concentration > MCP GW-1 Standard
2-Chlorophenol	Only analyzed in 1988 and concentration > MCP GW-1 Standard
2,4-Dichlorophenol	Only analyzed in 1988 and concentration > MCP GW-1 Standard
2,4,6-Trichlorophenol	Only analyzed in 1988 and concentration > MCP GW-1 Standard
2,4-Dinitrophenol	Only analyzed in 1988 and concentration > MCP GW-1 Standard
1,1,1-Trichloroethane	1996 concentration > MCP GW-1 Standard
1,1,2-Trichloroethane	Only analyzed in 1988 and concentration > MCP GW-1 Standard
1,4-Dichlorobenzene	Not analyzed in 1996 and 1994 concentration > MCP GW-1 Standard
Chloroform	1996 concentration > MCP GW-1 Standard
Cadmium	1988 concentration and 1994 detection limit > MCP GW-1 Standard
Iron	1994 concentration > MCP GW-1 Standard
Manganese	1994 concentration > MCP GW-1 Standard
Soil Gas	
Methane	1996 concentration > Imminent hazard LEL

[a/] See Tables 2.1 through 2.5.

both an upgradient and a downgradient location, and four soil gas samples were collected from within the landfill.

The soil gas samples collected from sampling point SG-1 are representative of background soil gas concentrations. The carbon dioxide, oxygen, and nitrogen concentrations are similar to atmospheric values and are indicative of clean soils. Methane was detected in soil gas at a concentration of 240,000 ppmv at sample location SG-3. Vinyl chloride, benzene, toluene, and xylene were the only other VOCs detected in a soil gas sample from soil gas point SG-3 in the central portion of the landfill. All other soil gas results collected at sampling point SG-3 were below the TWA PEL (Table 2.3).

2.4.2 Soil Contamination

Limited subsurface soil analytical data have been collected from the Landfill B site because the results of landfill subsurface sampling are rarely representative of actual site conditions in which waste is randomly distributed and not documented. However, OBG (1996a) performed a GPR survey to define the lateral extent and depth of landfill material. The results of the GPR survey suggest that no full waste containers or pools of non-ionic liquid contamination are located within Landfill B. The results of the GPR survey were confirmed using 13 test pits to locate the landfill boundary and observe the nature of fill material.

OBG (1996a) collected one background surface soil sample and three surface soil samples in the landfill. The location of the background sampling location (SS-04) was not documented in the OBG Phase III supplemental RI report. On the basis of MADEP (1993) and USEPA Region III (1996) risk-based surface soil screening criteria for industrial sites, no surface soil COPCs were identified.

2.4.3 Groundwater Contamination

Thirty-six permanent monitoring wells are currently installed at 20 locations at the Landfill B site. Monitoring wells are installed in 2-well clusters at 16 of the locations. The shallow cluster wells are designated with an (A) and are screened at the surface of the

aquifer. The deep cluster wells are screened approximately 40 to 50 feet bgs. Figures 2.5 through 2.7 show the previous groundwater sampling locations and detected COPC concentrations from the 1987, 1988, 1992, 1994, and 1996 groundwater investigations.

OBG (1996a) reported that in 1994, 1,1,1-trichloroethane (TCA) was detected at a concentration of 570 μg/L and 470 μg/L in groundwater samples from wells B-2 and B-2A, respectively. In 1996, the 1,1,1-TCA groundwater concentrations had decreased to 46 μg/L and 260 μg/L in samples from wells B-2 and B-2A (OBG, 1996a). Data on dissolved 1,1,1-TCA in Landfill B groundwater were not collected prior to 1994. McCarty (1996) reports that 1,1,1-TCA is biologically transformed to 1,1-dichloroethane (DCA), then to chloroethane, and finally to ethane in landfills where active methane fermentation is taking place. Data on methane and ethane in groundwater are not available; however, both 1,1-DCA, and chloroethane have been consistently detected in groundwater samples from monitoring wells B-2 and B-2A (Figure 2.5).

In 1996, the maximum detected 1,1-DCA concentration of 1,900 μg/L was detected in a groundwater sample from well B-2A. In 1987, the 1,1-DCA concentration in a groundwater sample from this well was 2.8 μg/L, and in a 1994 groundwater sample from well B-2A, the 1,1-DCA concentration had increased to 840 μg/L. Data collected in 1994 and 1996 indicate that measured concentrations of 1,1,1-TCA have been decreasing while the measured 1,1-DCA concentrations have increased. Because 1,1-DCA and chloroethane are not used in either domestic or industrial applications, their presence in site groundwater suggests the biological transformation of 1,1,1-TCA to the intermediate breakdown products 1,1-DCA and chloroethane. Although the groundwater velocities are relatively high, only 2.9 μg/L of 1,1-DCA was detected in 1996 in a groundwater sample from downgradient monitoring well B-6. This suggests that the transformation of 1,1,1-TCA is nearly complete within 300 feet of monitoring wells B-2 and B-2A. 1,1,1-TCA and 1,1-DCA are detected above MCP GW-1 standards (Table 2.1) only at monitoring wells B-2 and B-2A.

In 1988, 1,1,2-TCA was detected at 14 μg/L and 1.2 μg/L in groundwater samples from wells B-2 and B-2A (ES, 1988). The compound was not analyzed for again until 1996, and was not detected above the laboratory detection limits at any sampled well. However, the laboratory detection limits for groundwater samples from wells B-2 and B-2A were 12 μg/L and 5 μg/L, respectively. The detection limit for the remaining groundwater samples was 0.5 μg/L.

Vinyl chloride was detected in ES (1988) groundwater samples from monitoring wells B-2, B-6, B-6A, B-7, B-9, B-9A, and B-10 (Figure 2.5). Vinyl chloride was not detected in groundwater samples collected in 1988 by Geotech (1991). In 1994, vinyl chloride was detected at an estimated (J-flagged) concentration of 3.3J μg/L in a groundwater sample from well B-6. Vinyl chloride was not detected in 1996 groundwater samples; however, because of laboratory sample dilution, the detection limit for groundwater samples from wells B-2 and B-2A was above 10 μg/L.

1,4-Dichlorobenzene (DCB) has been detected above the MCP GW-1 standard in groundwater samples from wells B-2, B-6, B-7, and B-9A (Figure 2.5). In 1988 and 1994, the 1,4-DCB concentrations in groundwater samples from well B-2 were 18 μg/L and 19 μg/L, respectively. Groundwater samples from well B-9A had a 1,4-DCB concentration of 14 μg/L in 1988, and this analyte was not detected above a 10-μg/L detection limit in 1994 groundwater samples. In groundwater samples collected from wells B-6 and B-7 in 1988 and 1994, the 1,4-DCB concentrations decreased from 16 μg/L to 8.9 μg/L and from 9.1 μg/L to 2.0J μg/L, respectively.

Chloroform was detected above the MCP GW-1 standard in groundwater samples from monitoring wells B-2 and B-2A in 1996. The compound was previously not detected, however, in 1996 groundwater samples, the chloroform concentrations were 11J μg/L at well B-2 and 5.7 μg/L at well B-2A.

Methylene chloride was not detected in the 1988 groundwater sampling event. However, methylene chloride has been detected above the MCP GW-1 standard in the

1996 groundwater samples from monitoring wells B-2 (17J µg/L) and B-2A (16 µg/L). The only other methylene chloride detection in 1996 was at an concentration of 0.7J µg/L in a sample from well B-6 (Figure 2.5).

In 1988, bis-(2-ethylhexyl)phthalate was detected at concentrations of 22 µg/L and 110 µg/L in groundwater samples from monitoring wells B-6A and B-7A, respectively. This compound has not been analyzed in groundwater sampling events conducted since 1988.

The compounds 2-chlorophenol, 2,4-dichlorophenol, and 2,4,6-trichlorophenol were analyzed in 1988 groundwater samples and have only been detected in wells B-2 and B-9A (Figure 2.6). These compounds have not been analyzed in groundwater sampling events conducted since 1988. A groundwater sample from well B-9 had a 2-chlorophenol concentration of 240 µg/L. 2,4-Dichlorophenol was detected at concentrations of 160 µg/L and 180 µg/L in groundwater samples from wells B-2 and B-9A, respectively. Groundwater samples from wells B-2 and B-9A had 2,4,6-trichlorophenol concentrations of 300 µg/L and 320 µg/L, respectively. 2-Nitrophenol and 2,4-dinitrophenol have been detected above the MCP GW-1 standards in a groundwater sample collected in 1987 from monitoring well B-9A. Pentachlorophenol has been detected above the MCP GW-1 standard in groundwater samples collected in 1987 from wells B-1A, B-2, B-4, and B-9. Penta-chlorophenol was detected in groundwater samples collected in 1988 from all sampled wells. The distribution of the phenol compounds in site groundwater is not well documented and appears random.

In 1994, cadmium was detected at 0.0099 mg/L in a groundwater sample from monitoring well B-7, and manganese was detected at 1.3 mg/L and 4.1 mg/L in groundwater samples from monitoring wells B-6 and B-7, respectively. Prior to 1994, cadmium and manganese were detected in several wells; however, the concentrations have been decreasing, and these metals appear to be undergoing natural attenuation processes (Figure 2.7).

Natural attenuation also is reducing the dissolved iron and lead concentrations in groundwater. However, at some sampling locations lead and iron are still being mobilized, and not all dissolved concentrations have decreased over time. In 1994, the maximum dissolved iron concentration was 174 milligrams per liter (mg/L) in a groundwater sample from B-2. During the 1994 sampling event, iron also was detected in lesser concentrations and above the MCP GW-1 standard in groundwater samples from wells B-2A, B-3, B-3A, B-6, B-7, and B-8 (Figure 2.7). In 1994, lead concentrations above the MCP GW-1 standard were detected in samples from wells B-3, B-3A, B-4, B-5, and B-9. The maximum detected lead concentration in 1994 groundwater samples was detected at well B-3A at a concentration of 0.05 mg/L. The maximum detected dissolved lead concentration was 0.087 mg/L in a 1987 groundwater sample from well B-9A.

Because previous investigations focused on site characterization, available electron acceptors for *in situ* biodegradation, such as dissolved oxygen, have not been measured in the groundwater samples from the landfill site. Additional sampling is required to better define the mass transport characteristics and the geochemistry of the shallow aquifer. Section 4 summarizes the additional hydrogeologic characterization activities that will be necessary to support risk-based remediation at the landfill.

2.4.4 Sediment Contamination

ES (1988), Geotech (1991), and OBG (1996a) have collected a total of 7 sediment samples. Three of the sediment samples were collected from the drainage swale on the south side of the landfill. The remaining sediment samples were collected from locations along Stony Brook, and any detected contamination may have been derived from sources other than the landfill. Figure 2.8 presents the analytical results for the OBG (1996a) sediment sample (SED-1) and the ES (1988) sediment sample (SED-14) from the drainage swale.

Cadmium has been identified as the only sediment COPCs. Cadmium was not analyzed during the ES (1988) investigation, and the analytical results were not available for the Geotech (1991) investigation. A 1996 surface water sample from the drainage swale had

a cadmium concentration of 0.7 milligrams per kilogram (mg/kg). Note that the detected maximum concentration of cadmium in sediments also is greater than two times the mean background concentration (OBG, 1996a).

2.4.5 Surface Water Contamination

Chlorinated VOCs have been detected in surface water samples from sampling location SW-1 in the drainage ditch located in the swale south of the landfill (Figure 2.9). Vinyl chloride, methylene chloride, PCE, 1,1,2,2-tetrachloroethane, and 1,4-DCB have decreased to below detection limits in the period from 1987 to 1996. Similarly, 1,1-DCA concentrations have decreased from 320 µg/L in 1987 to 19 µg/L in 1996. Trichloroethene (TCE) was not analyzed in the 1987 and 1988 surface water sampling events, but was detected at a concentration of 56 µg/L in the 1996 sampling event. In 1987, 1,1-DCE was not detected in surface water samples; however, 1,1-DCE was detected at a concentration of 49 µg/L in the 1988 sampling event. The 1,1-DCE concentration decreased to 0.46 µg/L in the sample collected in 1996. The chlorinated pesticide, dieldrin, was only analyzed for in the 1996 sampling event. The measured dieldrin concentration in surface water was 0.055 µg/L.

Section 4 of this work plan describes the additional data that will be collected to confirm the potential for further contaminant discharge to surface water at the site. Data collected will also be used to evaluate the natural reaction mechanisms occurring at the interface between the shallow groundwater and the surface water systems present at the landfill.

SECTION 3

IDENTIFICATION OF SITE MODELS

It will be necessary to collect sufficient data to evaluate and compare the long-term effectiveness of various remedial/closure options at maintaining the No Significant Risk level and achieving applicable RAOs at and downgradient from Landfill B. Section 3.1 describes a conceptual site model for the Landfill B site, which includes possible source and release mechanisms, governing fate and transport processes, potential exposure points and routes, and potential human and ecological receptors. This conceptual site model is similar to that presented in the Phase II supplemental RI (OBG, 1996a). Section 3.2 describes the quantitative models that will be used to comparatively evaluate whether alternate cover designs provide an "equivalent" level of protection as that afforded by standard covers. Generation of landfill gases that could adversely impact ambient air quality or pose an explosive hazard are considered in this approach. Section 3.3 describes the fate and transport models that may be used to evaluate the effectiveness of natural chemical attenuation processes, as well as to investigate the need for additional groundwater and/or surface water protection components to supplement the effects of natural chemical attenuation processes.

3.1 CONCEPTUAL SITE MODEL

MADEP (1993) technical guidance on assessment and closure requirements for landfills specifies that a qualitative risk assessment, and possibly a quantitative risk assessment, must be completed to develop a suitable remedial/closure strategy. The guidance notes that the primary objective of a landfill risk assessment is to provide information on how contaminants emanating from the landfill may have affected nearby centers of population. However, a landfill risk assessment also can be used to answer

another important question: is a preferred remedial/closure approach sufficiently protective of potential receptors? The answer to this question will be one of the major elements of the "equivalency review" for alternative cover and groundwater protection system designs. Consequently, the Phase III RAP/Phase IV RIP will include a comparative assessment of potential residual risks under different remedial/closure options.

One of the first steps for both a qualitative and quantitative risk assessment is to construct a conceptual site model. A conceptual site model (CSM) qualitatively identifies how potential human and ecological receptors could come into contact with site-related contamination. The purpose of developing a CSM for Landfill B is to evaluate existing information about the characteristics of the site, including:

- Potential contaminant sources;
- COPCs in each affected environmental matrix;
- Release mechanisms (e.g., direct release, leaching and volatilization);
- Governing fate and transport processes (e.g., molecular diffusion, groundwater migration; chemical attenuation);
- Potential human and ecological receptors (e.g., current/future on-base workers, potential off-base residents, terrestrial wildlife):
- Exposure points (i.e., locations where receptors could come into contact with site-related contamination); and
- Routes of exposure (e.g., inhalation, incidental ingestion, and/or dermal contact).

Integrating this information into a CSM is necessary to identify the types of data necessary to quantify receptor exposures under different remedial/closure options. Consequently, the CSM will be used to define the nature of additional site

characterization activities required at Landfill B to support identification, selection, and implementation of a final remedial/closure option that minimizes contaminant migration and receptor exposure and satisfies the requirements of 310 CMR 19.140. A CSM was developed for Landfill B as part of the initial Phase III evaluation process (OBG, 1996a). The OBG CSM, with a few modifications, is shown schematically on Figure 3.1.

3.1.1 Potential Chemical Sources and Release Mechanisms

Figure 3.1 presents a schematic of the CSM for Landfill B. It defines, among other items, potential chemical sources, secondary sources such as affected media, and potential chemical release mechanisms. Primary chemical sources have been tentatively identified as buried drums that may contain liquids or residues and other buried wastes. However, as noted in Section 2, a GPR survey and excavation test pit program were performed at Landfill B in 1994 to locate the horizontal boundaries of the landfill, assess the depth of the fill material, and identify significant anomalies that may represent buried contaminants or persistent chemical sources. The GPR survey, which was conducted on a 100-foot by 100-foot grid system, showed no indications of full drums or pools of non-ionic liquid contamination. Additionally, although several crushed 55-gallon drums were encountered during the test pit program, no separate-phase liquid or liquid materials were noted. The drums themselves did not contain noticeable oily residues, and PID reading of the drum surfaces were non-detect (OBG, 1996a). Consequently, available data indicate that no significant primary chemical sources are present in the landfill. However, to verify (or disprove) the assumption of random chemical sources within the landfill, additional field activities to identify and characterize source areas within the landfill will be completed.

Secondary chemical sources include saturated or capillary fringe soils, soil gas vapors, and groundwater. No soil COPCs were identified as part of the updated BRA (OBG, 1996a) or the screening-level evaluation presented in Section 2 of this work plan. Clean surface soils were placed over the landfill as a temporary cover, and it is

assumed that they have not been in direct contact with chemical sources buried within the landfill. The thin layer of soils beneath the landfill waste and above the groundwater may be a secondary source of contamination at Landfill B. A comprehensive shallow groundwater screening program will be conducted at the site, as described in Section 4 of this work plan, to identify potential areas of secondary chemical sources. Due to the heterogeneous nature of landfill material and relatively thin layer of soil between the waste material and the groundwater, actual groundwater samples from directly beneath suspected source areas are expected to provide the most accurate estimate of leachate generation potential. A limited number of soil samples collected at or near the groundwater table also will be collected as part of this additional field work.

The contaminant release mechanisms incorporated into the CSM shown on Figure 3.1 are as follow: (1) volatilization into the atmosphere; (2) partitioning from soil gas or capillary fringe soil into groundwater; and (3) groundwater discharge into surface water (and precipitation from surface water into sediment). In the 1996 BRA (OBG, 1996a), the only exposure pathway to human receptors assumed to be completed involved surface water and sediments. Exposure pathways involving soil were determined to be incomplete due to assumed absence of contamination within the landfill soil cover and the absence of COPCs in sampled subsurface soils. Exposure pathways involving air were assumed to be incomplete/insignificant due to the low frequency of VOC detections and the effects of dispersion and degradation in ambient air. Exposure pathways involving groundwater were assumed to be incomplete given current and planned groundwater usage on base. The 1996 BRA recommends implementation of at least a groundwater AUL to ensure that groundwater underlying and immediately downgradient from Landfill B is not extracted for beneficial uses. As part of the proposed Phase III evaluation, release mechanisms that may be part of both complete and incomplete exposure pathways for human receptors will be quantitatively investigated. Of specific interest will be the potential for natural chemical attenuation processes to interrupt potential exposure pathways involving air, groundwater, and

surface water. The potential explosive hazard of methane gas and possible gas controls will be considered in the cover design evaluation.

Furthermore, potentially completed exposure pathways to ecological receptors were identified during the Method 3 Stage I environmental screening (OBG, 1996a). The Stage I environmental screening initially considered that chemical exposure pathways involving biological receptors could involve air, surface soil, groundwater, sediment, surface water, and biota. However, after a qualitative exposure pathways analysis, the Stage I environmental screening concluded that potentially significant completed exposure pathways to ecological receptors at Landfill B involved only surface soil, groundwater, surface water, and sediment. However, given the lack of landfill contamination in the soil cover as noted above, surface soil is not considered an exposure medium for the Phase III risk evaluation. Data relevant to completing a Stage II Environmental Risk Characterization as part of the Phase III RAP/Phase IV RIP will be collected as described in Section 4.

3.1.2 Fate and Transport Processes

Fate and transport processes included in the CSM for Landfill B include (1) molecular diffusion of soil gases through unsaturated soil, (2) air dispersion, (3) groundwater migration, and (4) surface water migration. The presence of potentially explosive concentrations of methane need to be more fully investigated to ensure that any alternate cover system design include adequate soil gas/air emissions control components. The actual rate of air emissions from potential primary and secondary chemical sources will be investigated as described in Section 4 of this work plan, and may be modeled using the methods described in Sections 3.2 and 3.3. These data will be necessary to conclusively demonstrate that exposure pathways are incomplete or to estimate exposure-point concentrations under different remedial/closure options.

Residual capillary fringe contamination can also be expected to partition into the underlying groundwater and to migrate downgradient as dissolved constituents. In

addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, adsorption), some of these dissolved constituents may be slowly removed from the groundwater system by other naturally occurring destructive mechanisms, such as biodegradation, abiotic oxidation, and hydrolysis. The effects of these natural chemical attenuation processes on constituents dissolved in groundwater and surface water will be investigated using analytical data collected as part of the proposed supplemental Phase III evaluation and a quantitative, analytical fate and transport model such as AT123D. These data are necessary to quantitatively demonstrate that an alternate cover and groundwater protection system design provides an "equivalent" level of protection for groundwater and surface water resources (310 CMR 19.113). Additionally, these data will support development of design criteria for monitoring the performance of natural chemical attenuation processes as part of a temporary and possibly permanent closure strategy. Data collection and analysis requirements are discussed in subsequent sections of this work plan.

3.1.3 Potential Human and Ecological Receptors

Base maintenance workers were identified in the updated BRA (OBG, 1996a) as the only onsite human receptors that reasonably could be involved in potentially completed exposure pathways at Landfill B. The landfill is considered to be part of a commercial/industrial area of the base, and no plans for redevelopment or reuse beyond landfill closure in accordance with 310 CMR 19.140 and the MCP are being contemplated. Routes of exposure quantitatively considered in the OBG risk estimates included dermal contact with and incidental ingestion of surface water, sediments, and surface soils. Potential risks to offsite human receptors were not quantitatively estimated, although the BRA concluded that No Significant Risk to public welfare existed. In addition to verifying that the current No Significant Risk level can be maintained over time at Landfill B, the supplemental Phase III evaluation will be completed to ensure that the major performance standards for landfill covers and groundwater protection systems are met. Of specific interest is that any recommended

alternate cover and groundwater protection system design minimize migration of landfill leachate into the underlying groundwater to the maximum practicable extent and minimize the impact to downgradient groundwater and receiving surface waters during the closure/post-closure period.

In terms of potential ecological receptors, the Massachusetts Natural Heritage Atlas (MNHA) (Massachusetts Department of Fish and Wildlife, 1996) indicates that much of Westover ARB, including the Landfill B vicinity, is a high-priority site of rare species habitats and exemplary natural communities. Three avian species, the grasshopper sparrow, which is listed as a species of special concern by Massachusetts; the vesper sparrow, which is listed as threatened in Massachusetts; and the upland sandpiper, which is listed as endangered by Massachusetts, have been reported in the vicinity of the landfill by MADEP and Scott Melvin, who surveyed grassland birds on the base (Melvin *et al.*, 1994). Additionally, a vernal pool identified just south of the southern landfill boundary (Whitlock *et al.*, 1994) and a ponded drainage swale north of the landfill may attract terrestrial or avian wildlife on a seasonal basis. A drainage swale also is located along the southern edge of the landfill (Figure 2.9). Stony Brook is located approximately 0.25 mile east of the landfill. Data will be collected to determine if surface water features near the landfill support aquatic organisms or wetland vegetation, and what if any connection there is between these surface waters and Stony Creek.

3.1.4 Exposure Points and Exposure Routes

An exposure point is a location at which any potentially exposed receptor could come into contact with site-related contamination. On-base contaminated media will be considered possible human receptor exposure points only for those base personnel who currently or may in the future have access to the landfill and for potential off-base receptors who may contact contaminated groundwater (or surface water) that may migrate offsite. Potential onsite exposure points initially included in this CSM include breathing zone air within the perimeter of the landfill property; subsurface soils and

groundwater underlying and downgradient from the site that may be impacted by direct waste releases or landfill leachate; and surface water and sediments in the drainage swales to the north and south of the landfill. Potential offsite exposure points include air and groundwater at the perimeter of the base downgradient from the landfill, and surface water at the discharge point to Stony Brook. Several of these potential exposure points may be eliminated from the final evaluation should fate and transport data demonstrate that site-related contamination could not reach these locations at concentrations that exceed protective remedial/closure concentration goals (i.e., the exposure pathway is incomplete).

Probable exposure routes are dependent upon which receptors come into contact with what contaminated media. Based on a review of available data and the need to establish risk-based remedial/closure goals for all affected media, the following exposure routes are considered viable for current and potential future human receptors and are incorporated into the CSM: (1) inhalation of VOCs in ambient air; (2) incidental ingestion of contaminated groundwater, surface water, and sediment; and (3) incidental dermal contact with contaminated groundwater, surface water, and sediment. This approach is consistent with that included in the updated BRA (OBG, 1996a), except that exposure pathways involving air and incidental contact with COPCs dissolved in shallow groundwater will be quantitatively considered. Inclusion of exposure routes for groundwater is consistent with the need to establish risk-based remedial/closure concentration goals for the landfill property, and to protect groundwater and surface water resources downgradient from the landfill property.

As noted previously, a Stage II Environmental Risk Characterization was recommended in the Phase II supplemental RI (OBG, 1996a). A Stage II Environmental Risk Characterization is used to determine whether there is an indication of the potential for ecological harm and/or evidence of ecological harm. Similar to a human health risk assessment, the Stage II Environmental Risk Characterization should begin with a preliminary characterization of potential receptors, exposure points, and a

screening-level assessment of the potential for toxic effects (310 CMR 40.0995(4)). If ecological COPCs are identified in the screening assessment, further quantitative analysis of ecological risks should be conducted. Should a quantitative analysis be necessary, it is anticipated that available state and USEPA guidance for conducting ecological risk assessments will be followed.

3.2 QUANTITATIVE EVALUATION OF VARIOUS COVER DESIGNS

In order to demonstrate that an alternate cover system design will provide an "equivalent" level of protection as that afforded by the standard landfill cover approach, the Phase III RAP/Phase IV RIP must first document that each of the general performance standards for landfill final cover systems (310 CMR 19.112) will be satisfied. The general performance standards for a final cover design include:

- Minimizing percolation of water through the final cover system into the landfill to the greatest extent practicable;
- Promoting proper drainage of precipitation;
- Minimizing erosion of the final cover;
- Facilitating venting and control of landfill gas;
- Ensuring isolation of landfill wastes from the environment; and
- Accommodating settling and subsidence of the landfill such that the above performance standards will continue to be met.

Pursuant to 310 CMR 19.112(3), a standard landfill final cover system design would consist of a subgrade layer; a landfill gas venting layer (or an active gas collection and extraction system); a low-permeability layer or layers; a drainage layer; filter material; a layer capable of supporting vegetation; the vegetative cover; and any other components necessary to meet the general performance standards. The alternate cover

system design proposed to be implemented at Landfill B would provide a uniform grading over the surface of the landfill to minimize exposure to the soil/fill and also to minimize erosion and migration of debris through a revegetated surface (OBG, 1996b). The proposed alternate cover system design consists of re-grading existing surface materials across the 13.3 acres to minimize surface water ponding and installing a graded, 1-foot soil layer capable of supporting vegetation.

3.2.1 HELP Model

A quantitative performance evaluation of a standard cover and at least one alternate engineered cover system design will be completed as part of the Phase III RAP/Phase IV RIP. As discussed previously, a primary objective of a landfill final cover is to minimize infiltration of precipitation and to limit percolation of water through landfilled materials. To determine whether an alternate cover design system provides an "equivalent" level of protection, it will be necessary to calculate the amount of precipitation infiltration percolating through each of the cover components. If a reduced number of cover components effectively meets the general performance standards, the proposed alternate cover design system may be deemed "equivalent." Estimating the amount of infiltration also is important in predicting the potential for contaminant leaching.

The Hydrologic Evaluation of Landfill Performance (HELP) computer model, version 2.05, will be used to estimate the amount of infiltration and percolation through final engineered cover designs. The HELP model was developed by the U.S. Army Corps of Engineers Waterways Experiment Station for the USEPA to facilitate rapid and economical estimations of the water movement through and out of landfills. HELP is a quasi-two-dimensional computer code that models landfill performance with respect to the hydrologic cycle. HELP has the ability to model landfill components including various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils, as well as synthetic membrane covers and lines. HELP has been selected because of its widespread acceptance in the engineering

community. The HELP model also can be updated throughout the detailed design process to optimize the final engineered cover design.

3.2.2 Estimates of Leaching Potential

In addition to using the HELP model predictions of infiltration rate to evaluate the effectiveness of the final engineered cover design, the results from the HELP model can be coupled with groundwater data to estimate the long-term leaching potential from landfilled material/soils into underlying groundwater. This is an important step toward documenting attainment of at least one of the general performance standards for landfill final covers. Additionally, this information will be useful in determining whether natural chemical attenuation processes will be sufficient, in the absence of an engineered groundwater protection system, to minimize the migration of leachate out of the landfill into underlying groundwater (310 CMR 19.110).

Because of the heterogeneous nature of landfill materials and the relatively thin soil layer separating the waste materials from the groundwater, standard vadose zone leaching models such as VLEACH and VS2DT will be difficult to apply at this site. An alternate approach to estimating the landfill leaching potential is proposed. Rather than using a model to estimate the concentration and distribution of leachate beneath the landfill, actual shallow groundwater samples will be collected from 50 points across the landfill site using a 100 foot by 100 foot grid spacing. Statistical methods will be used to estimate the distribution and average concentration of groundwater COPCs that are emanating from landfill waste. Thus, actual leachate concentrations will be used as the source term for groundwater fate and transport models such as SOLUTE or AT123D that will be used to predict the natural attenuation and migration of COPCs.

3.2.3 Estimating Air Quality Impacts

Based on existing soil gas data described in Section 2, only methane was determined to be potential gas-phase COPC at this site. In the event that additional soil gas survey data reveals any additional COPCs, it will be necessary to evaluate potential soil gas

emissions to the atmosphere. To determine whether subsurface sources could cause exposure-point concentrations that may pose an unacceptable risk to potential receptors via the inhalation exposure route, several different kinds of chemical flux and atmospheric transport equations will be coupled to simulate the concentrations of any volatile COPCs present in outdoor ambient air under normal atmospheric conditions. The goal of this modeling effort will not include estimating the amount of VOCs, including methane, that could be generated by the landfill during the closure/post-closure period. All available soil gas data, including the proposed screening soil gas survey data, will be included in this modeling effort. Most of the equations are based on the predictive contaminant migration equations presented by ASTM (1995) in the *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.*

Three different types of COPC migration equations may be used to predict the transport of VOCs from subsurface sources through unsaturated soils and manmade structures (e.g., engineered cover), and within ambient air. Equilibrium partitioning equations will be used to estimate the mass of volatile COPCs that theoretically could partition from dissolved contamination and any identified residual sources (e.g., contaminated soil). Flux equations will then be used to estimate that mass of volatile COPCs that migrated to the target mixing area (i.e., outdoor ambient atmosphere and enclosed space). Finally, simple "box" mixing equations will be used to translate flux measurements into predicted exposure-point concentrations for air.

3.3 QUANTITATIVE EVALUATION OF NATURAL CHEMICAL ATTENUATION

The proposed remedial/closure option for groundwater contamination is natural chemical attenuation (OBG, 1996b). The main advantages of natural chemical attenuation include: (1) organic contaminants can be transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination; (3) the

process is nonintrusive (i.e., involves minimal drilling and support equipment) and allows continuing use of the land during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than natural chemical attenuation because contaminants may be transferred into the atmosphere during remediation activities; and (5) natural chemical attenuation is far less costly than conventional, engineered remedial technologies. The main limitation of natural chemical attenuation is that, depending on the types of chemical contaminants at a site, it may be a long-term solution that requires regular monitoring to confirm its progress. To quantitatively assess the potential for natural chemical attenuation processes to minimize migration of contaminants dissolved in groundwater and/or detoxify/destroy organic contaminants over time, additional site characterization data will need to be collected, and a groundwater flow and solute transport model will need to be developed as part of the Phase III RAP/Phase IV RIP.

Natural chemical attenuation processes can be divided into two separate categories: non-destructive mechanisms and destructive mechanisms. Non-destructive mechanisms may bring about a reduction in contaminant mass and concentration due primarily to changes in chemical form (e.g., liquid to vapor phase) or dilution (e.g., dispersion) or accumulation with little migration (e.g., adsorption, bioconcentration) within the environment. Natural non-destructive attenuation of organic contaminants can occur through adsorption, dispersion, volatilization, and bioaccumulation/biomagnification. These processes do not strictly qualify as contaminant destruction/detoxification processes, but they may play a significant role in interrupting potentially complete exposure pathways at many sites. In comparison, destructive attenuation processes bring about a reduction in the total mass, concentration, persistence, and sometimes toxicity of contaminants. Natural destructive attenuation of organic contaminants can include aerobic biodegradation, anaerobic biodegradation, photolysis, hydrolysis, and photo-oxidation. Inorganic constituents such as cadmium are not subject to natural destructive chemical attenuation processes; however, their fate and transport in the environment is largely affected by non-destructive chemical attenuation processes.

Table 3.1 presents a qualitative summary of the relative importance of different natural chemical attenuation mechanisms on each of the COPCs identified for Landfill B. Many of the organic COPCs are subject to significant biodegradation, which will be the primary destructive chemical attenuation process investigated as part of the proposed additional field work. For example, for many organic chemicals, such as 1,4-DCB and the phenols, rapid natural biodegradation can occur naturally when sufficient oxygen is available in the soil and groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen rather than by the lack of nutrients such as nitrogen or phosphorus. Anaerobic biodegradation also is likely to play a significant role in the destruction/detoxification of organic COPCs at Landfill B. Organic compounds such as 1,1,2,2-tetrachloroethane (PCA) are subject to significant anaerobic degradation. Destruction of these compounds via anaerobic degradation occurs primarily when microorganisms catalyze the transfer of electrons from electron donors to electron acceptors. Electron donors can be organic carbon and fuel hydrocarbon compounds. Electron acceptors are elements or compounds that occur in relatively oxidized states. Electron acceptors can be inorganic compounds such as nitrate, sulfate, manganese, ferric iron, and carbon dioxide or organic compounds such as TCE.

Analytical data relevant to assessing the potential for natural biodegradation processes to destroy/detoxify contaminant mass will be collected as part of the field activities proposed herein (Section 4). To estimate the impact of natural biodegradation on the fate and transport of COPCs in saturated media at Landfill B, two important lines of evidence will be demonstrated as part of this project. The first is a documented loss of COPCs at the field scale. Historical analytical data will be used in conjunction with aquifer hydrogeologic parameters such as groundwater seepage velocity and dilution to demonstrate that a reduction in the total contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass balance calculations to show that a decrease in contaminant and electron acceptor (e.g., oxygen, nitrate, sulfate) concentrations can be correlated to increases in metabolic

TABLE 3.1
CHEMICAL ATTENUATION CHARACTERISTICS OF COPCS
LANDFILL B PHASE III RAP/PHASE IV RIP WORKPLAN
WESTOVER ARB, MASSACHUSETTS

Chemical	Nondestructive Mechanisms			Destructive Mechanisms				Literature-Reported Half-Lives (days)			
	Adsorption	Volatility	Bioaccumulation	Aerobic Biodegradation	Anaerobic Biodegradation	Photolysis/ Hydrolysis	Photo-oxidation	Soil	Ground-water	Surface Water	Air
Organics											
1,1,1-trichloroethane	Low	High	Low	Very Low	Very Low	High	Low	140 - 280	140 - 500	140 - 280	225 - 2,200
1,1,2,2-tetrachloroethane	Low	High	Low	Low	High	High	Medium	< 45	< 45	< 45	9 - 90
1,1,2-trichloroethane	Low	High	Low	Low	Low	Medium	Medium	150 - 365	150 - 730	150 - 365	9 - 82
1,1-dichloroethane	Low	High	Low	Medium	Medium	Low	High	32 - 150	65 - 350	32 - 150	10 - 105
1,1-dichloroethene	Low	High	Low	Low	Medium	Low	Medium	28 - 180	56 - 132	28 - 180	< 5
1,4-dichlorobenzene	High	High	Low	High	Low	Low	Low	30 - 180	60 - 365	30 - 180	9 - 85
2,4,6-trichlorophenol	High	High	High	High	Medium	High	Medium	7 - 70	14 - 1,800	< 4	5 - 52
2,4-dichlorophenol	Medium	Low	High	High	High	High	High	< 9	17 - 355	< 4	5 - 10
2,4-dinitrophenol	Low	Low	Low	Low	Low	High	High	NA	21 - 48	NA	< 2
2-chlorophenol	Medium	Low	Low	High	High	Medium	Medium	14 - 47	15 - 36	< 4	< 4
Benzene	Low	High	Low	High	High	Low	Medium	5 - 16	10 - 700	5 - 16	2 - 21
Bis(2-ethylhexyl)phthalate	Strong	Low	Medium	High	Low	Low	Low	5 - 23	10 - 389	5 - 23	< 1
Chloroform	Low	High	Low	High	High	Low	Low	30 - 180	60 - 730	30 - 180	25 - 260
Dieldrin	Strong	Low	Strong	Low	Low	Low	Low	2 - 7 yrs.	> 120	> 14	NA
Ethylbenzene	Low	High	Low	High	High	Low	Low	7 - 60	14 - 365	7 - 30	< 5
Methane	Low	High	Low	Low	Low	Low	Low	> 70	> 5	< 2	3 - 6 yrs.
Methylene chloride	Low	High	Low	High	Medium	Low	High	7 - 28	14 - 56	7 - 28	19 - 192
Tetrachloroethene	Low	High	Low	Medium	Medium	NA	Medium	180 - 365	365 - 730	180 - 365	16 - 160
Toluene	Medium	High	Low	High	High	Low	Low	7 - 60	14 - 365	7 - 30	< 5
Trichloroethene	Low	High	Low	Low	Medium	Low	Low	180 - 365	> 300	180 - 365	< 12
Vinyl chloride	Low	High	Low	High	Low	Low	Medium	30 - 180	60 - 2,950	30 - 180	< 3
Xylenes	Medium	High	Low	High	High	None	Medium	7 - 28	14 - 365	7 - 28	< 2
Inorganics											
Cadmium	Medium	Low	High	NA[a]	NA	NA	NA	NA	NA	NA	NA
Iron	Medium	Low	Low	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	Medium	Low	Medium	NA	NA	NA	NA	NA	NA	NA	NA

[a] NA = not applicable.

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degradation byproduct concentrations (e.g., carbon dioxide, methane, ferrous iron). Microcosm studies will not be a component of this project. Additionally, analytical data relevant to investigating the potential significance of non-destructive attenuation processes such as adsorption will be collected. These data are required to develop quantitative estimates of the effectiveness of natural chemical attenuation processes, and to establish suitable design criteria for this element of the landfill remedial/closure strategy.

Once these data are available, several well-documented and widely-accepted analytical or numerical models are available for modeling the fate and transport of COPCs under saturated conditions at Landfill B. Because subsurface contaminant transport models incorporate a number of theoretical assumptions about the natural processes governing the transport and fate of contaminants, all modeling involves simplifying assumptions concerning parameters of the physical and chemical system that is being simulated. These parameters will influence the type and complexity of the equations that are used in the model to represent the system mathematically. Models generally are classified as analytical or numerical, depending on the mathematical formulation and solution of the governing flow and transport equations.

Analytical models generally are used to estimate the impacts of contamination on a site given the qualifying assumptions used to develop the equation. Analytical models are the most prevalent type of code used to estimate contaminant behavior in risk-based remedial/closure projects. Analytical models are intended to give order-of-magnitude results because a number of potentially important processes are treated in the model in an approximate manner or are ignored entirely. Because of the simplifying assumptions, analytical models generally overestimate the impact of contamination at a site and the predictions generally are considered conservative. This is important because models are only to be considered tools to help facilitate remedial planning and implementation. The Air Force anticipates that use of a conservative approach will likely be preferred by MADEP.

It may be appropriate and prudent to use an analytical model such as AT123D or SOLUTE to simulate contaminant transport at Landfill B within the groundwater and from the groundwater to potentially receiving surface water bodies under different remedial/closure options. These models enable the user to account for both the non-destructive attenuation processes such as advection, dispersion, and adsorption, as well as the destructive attenuation processes such as natural aerobic and anaerobic biodegradation. The Air Force intends, as part of preparation of the proposed Phase III RAP/Phase IV RIP, to collect site-specific evidence of natural chemical attenuation processes and incorporate this information into the remedial/closure design.

The analytical model AT123D would allow for modeling of contaminant contributions from point source(s), if any are identified during the proposed groundwater screening survey, as well as contaminant transport, adsorption, and possibly decay (if mass removal can be documented and quantified). Model output includes concentration distributions in space and time. The analytical model SOLUTE may be necessary to explore both one- and two-dimensional contaminant transport. Both models have been applied at hundreds of sites. The numerical US Geological Survey (USGS) two-dimensional (2-D) solute transport method of characteristic (MOC) model can be used, if necessary, to simulate the effects of both non-destructive and destructive attenuation processes on contaminant mass over time under different remedial/closure options.

The selected groundwater flow and contaminant transport model will be run, and the results will be compared against a known (observed) condition. This process is known as model calibration. Following calibration, model simulations will be run to predict future consequences at Landfill B under different remedial/closure options. Because any groundwater flow and contaminant transport model is influenced by uncertainty related to the inability to define the exact spatial and temporal distribution of aquifer and chemical parameter values at the site, a quantitative sensitivity analysis will be performed. This sensitivity analysis may either be deterministic (i.e., individual model

input parameters will be varied over reasonable ranges to establish the effect of uncertainty on the model) or probabilistic. The results of this sensitivity analysis will be presented and discussed to constrain or "bound" predicted results and to evaluate the reasonableness of the model predictions.

The additional field work and analysis to be completed as part of the proposed Phase III RAP/Phase IV RIP is aimed at providing scientific evidence in support of the positive effects of natural chemical attenuation. The type and magnitude of these effects will be factored into the development of a final remedial/closure strategy and design for Landfill B. The effectiveness of natural chemical attenuation processes, in concert with other remedial/closure technologies, will be quantitatively compared against at least one more traditional groundwater remediation method, such as pump-and-treat. The objective of the proposed fate and transport calculations and updated risk analysis is to develop a final remedial/closure strategy and conceptual design that will both protect current and future receptors from adverse exposures to any site-related contamination and satisfy relevant requirements of 310 CMR 19.140 and 310 CMR 40.0000.

SECTION 4

PROPOSED SITE CHARACTERIZATION ACTIVITIES

In order to determine if natural chemical contaminant attenuation mechanisms are operating at the Landfill B site and to support preparation of the Phase II RAP/Phase IV RIP, additional data are required. The additional data needs include:

- Identification and characterization of any source areas within the landfill;
- Identification of field-scale evidence of natural chemical attenuation, specifically bioattenuation;
- Quantification of natural chemical attenuation processes and rates in groundwater, soil, and surface water;
- Determination of the vertical hydraulic and geochemical interactions within the shallow aquifer; and
- Evaluation of the ability of an alternate landfill cover design to reduce direct releases and leaching of contaminants and soil gas emissions while promoting continued natural chemical attenuation.

In addition to providing data to demonstrate the occurrence of natural attenuation at the site, the proposed characterization activities also will further delineate the nature and extent of contamination; provide data for fate and transport analyses; support quantitative comparative analysis of remedial/closure options; and development of RAOs, final concentration goals and monitoring/design criteria. Samples from background and contaminated areas will be collected and analyzed for individual

COPCs and indicator compounds. Compound-specific analytical procedures will be used to determine the lateral and vertical extent and volume of contaminated media at Landfill B. Selection and design of an appropriate remedial/closure option for the landfill will require chemical-specific data for both established COPCs and geochemical indicators of chemical attenuation.

4.1 GENERAL DATA NEEDS

Additional soil gas, soil, groundwater, surface water, and sediment sampling will be performed to measure the concentrations, distribution, and mass of contaminants and electron acceptors at the site. To facilitate collection of these data, new soil borings, groundwater monitoring points, surface water/sediment sampling stations, and vapor monitoring points will be installed at the site. Parsons ES intends to investigate the potential for vertical migration within the surficial aquifer by collecting groundwater samples from nested monitoring points with screened intervals at approximately 5-10 feet bgs and 50-55 feet bgs. In order to support quantitative fate and transport modeling efforts, geochemical sampling and analysis is proposed and hydraulic properties of the shallow aquifer will be determined by aquifer tests.

Current information on potential ecological receptors and sensitive habitats in the vicinity of the landfill also will be collected. Any additional existing information not incorporated into this work plan will also be reviewed and used to the extent practicable to prepare the Phase II RAP/Phase IV RIP for Landfill B. Site characteristics listed in the following subsections will be determined during the field investigation phase of the proposed work.

4.1.1 Soil Gas Data

Soil gas measurements will be used to determine the following site characteristics:

- Estimated flux rate of VOCs to the surface, if any;

- Soil gas oxygen, carbon dioxide, methane, and total volatile hydrocarbons concentrations by depth; and

- Potential location of significant, unknown VOC sources.

4.1.2 Soil Data

Both vadose zone (unsaturated), landfilled, and phreatic zone (saturated) soil characteristics to be determined include:

- Detailed stratigraphic analysis of subsurface media to support cover design and modeling efforts;

- Total organic carbon (TOC) content and pH;

- Estimated vertical and lateral extent of landfilled material and any chemical contamination that is being directly released to groundwater;

4.1.3 Groundwater and Hydrogeologic Data

Physical hydrogeologic characteristics that will be determined include:

- Depth from measurement datum to the groundwater surface;

- Estimation of vertical gradients within the shallow aquifer;

- Location of potential groundwater recharge and discharge;

- Hydraulic conductivity through slug tests;

- Determination of groundwater velocity using estimated values for dispersivity and effective porosity;

- Determination of groundwater contaminant velocity using measured aquifer TOC values.

Physiochemical hydrogeologic characteristics of the shallow aquifer groundwater that will be determined:

- Determination of lateral and vertical transport and extent of dissolved COPCs immediately beneath Landfill B;
- Field measurement of dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, specific conductance, and pH;
- Field measurement of dissolved carbon dioxide, total alkalinity(as calcium carbonate), ferrous iron (Fe^{2+}), total iron, total manganese, nitrate (NO_3^-), sulfate (SO_4^{-2}), and sulfide;
- Laboratory analysis of TOC and methane (CH_4) on selected samples; and
- Laboratory of analysis of COPCs for water and sediment matrices including total dissolved species for metals COPCs;

4.1.4 Surface Water Data

Surface water data that will be determined during site characterization include:

- Field measurement of pH, ORP, specific conductance, temperature, and DO;
- Field measurement of dissolved carbon dioxide, total alkalinity (as calcium carbonate), Fe^{2+}, total iron, total manganese, NO_3^-, SO_4^{-2}, sulfide, and dissolved TOC; and
- Laboratory of analysis of COPCs for water and sediment matrices, including total and dissolved species for metals COPCs.

4.1.5 Sediment Data

Sediment data to be collected from surface water bodies that potentially receive landfill discharges or runoff include:

- Field measurement of pH:
- Laboratory analysis of pH and TOC; and
- Laboratory analysis of COPCs for surface water and sediment matrices, including total and soluble (extractable) fractions of metals COPCs.

4.1.6 Analytical and Other Data

Table 4.1 lists the chemical analytical protocol for each of the environmental media to be sampled in support of preparing the proposed Phase III RAP/Phase IV RIP for Landfill B. This table also presents the detection limits required to support quantitative fate and transport analyses, verification of the No Significant Risk Level, and compliance with method 1 or alternate risk-based closure concentration goals. Additional site-specific data necessary to support preparation of the Phase III RAP/ Phase IV RIP include:

- General climatic data, including prevailing wind speed and direction, average precipitation (as snow and rain), evapotranspiration rates, and temperature range:
- Existing and proposed land use plans for portions of Westover ARB, including Landfill B and downgradient areas;
- Presence or suspected present of sensitive subpopulations such as threatened or endangered species, or special-concern habitats and ecosystems;
- Water-supply well locations and groundwater use information for areas likely to be affected by groundwater migration;
- Groundwater/surface water interaction;
- Surface water flow rates, monthly volumes, and discharge locations; and
- Other site-specific data to justify exposure assumptions and design specifications.

TABLE 4.1
ANALYTICAL METHODS AND REPORTING LIMITS
LANDFILL B PHASE III RAP/PHASE IV RIP WORKPLAN
WESTOVER ARB, MASSACHUSETTS

Targeted Analyte by Matrix	Analytical Method	Field or Fixed-Base	Soil Gas MDL [a]	Soil Gas Units	Site-Specific Soil MDL	Soil Reporting Limit	Soil Units	Site-Specific Sediment MDL	Sediment Reporting Limit	Sediment Units	Site-Specific Groundwater MDL	Groundwater Reporting Limit	Groundwater Units	Site-Specific SurfaceWater MDL	SurfaceWater Reporting Limit	Surface Water Units
SEDIMENT																
Cadmium	SW3050A/SW7131A	Fixed-Base [b]	- [c]	-	-	-	-	0.01	0.1	mg/kg	-	-	-	-	-	-
Total Organic Carbon	SW5030	Fixed-Base [b]	-	-	-	-	-	0.05	0.05	%	-	-	-	-	-	-
SURFACE WATER																
1,1-Dichloroethene	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.12	1.2	µg/L
Trichloroethene	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.1	1.0	µg/L
1,1-Dichloroethane	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.04	0.4	µg/L
Vinyl Chloride	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.11	1.1	µg/L
Methylene Chloride	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.03	0.3	µg/L
Tetrachloroethylene	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.14	1.4	µg/L
1,1,2,2- Tetrachloroethane	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.04	0.4	µg/L
1,4-Dichlorobenzene	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.03	0.3	µg/L
Dieldrin	SW3510B/SW8081	Fixed-Base [b]	-	-	-	-	-	-	-	-	-	-	-	0.044	0.44	µg/L
GROUNDWATER																
Ferrous Iron	H8146	Field	-	-	-	-	-	-	-	-	0.01	0.024	mg/L [d]	-	-	-
Hydrogen Sulfide	H8131	Field	-	-	-	-	-	-	-	-	0.01	0.024	mg/L	-	-	-
Sulfate	N-601	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.025	0.05	mg/L	-	-	-
Nitrate & Nitrite	E353.1	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.025	0.05	mg/L	-	-	-
Oxidation/Reduction Potential (ORP)	Direct-reading meter	Field	-	-	-	-	-	-	-	-	-	0.01	mV	-	-	-
Oxygen	Direct-reading meter	Field	-	-	-	-	-	-	-	-	-	0.5	%	-	-	-
pH	Direct-reading meter	Field	-	-	-	-	-	-	-	-	-	0.1	pH units	-	-	-
Conductivity	Direct-reading meter	Field	-	-	-	-	-	-	-	-	-	0.1	umhos/cm	-	-	-
Temperature	Direct-reading meter	Field	-	-	-	-	-	-	-	-	-	1	degrees C	-	-	-
Alkalinity	H8221	Field	-	-	-	-	-	-	-	-	20	20	mg/L	-	-	-
Carbon Dioxide	H8223	Field	-	-	-	-	-	-	-	-	0.01	1.25	mg/L	-	-	-
Chloride	N-601	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.1	0.5	mg/L	-	-	-
Methane	RSKSOP-175 & -147	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.0005	0.001	mg/L	-	-	-
Ammonia	E350.1	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.025	0.05	mg/L	-	-	-
Total Organic Carbon	RSKSOP-102	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.3	0.4	mg/L	-	-	-
Total Inorganic Carbon	RSKSOP-102	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.005	0.1	mg/L	-	-	-
1,1- Dichloroethane	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.04	0.4	ug/L [e]	-	-	-
Vinyl Chloride	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.11	1.1	ug/L	-	-	-
bis(2-Ethylhexyl)phthalate	SW3510B/SW8270B	Fixed-Base [b]	-	-	-	-	-	-	-	-	1	10	ug/L	-	-	-
Methylene Chloride	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.03	0.3	ug/L	-	-	-
2- Chlorophenol	SW3510B/SW8270B	Fixed-Base [b]	-	-	-	-	-	-	-	-	1	10	ug/L	-	-	-
2,4- Dichlorophenol	SW3510B/SW8270B	Fixed-Base [b]	-	-	-	-	-	-	-	-	1	10	ug/L	-	-	-
2,4,6- Trichlorophenol	SW3510B/SW8270B	Fixed-Base [b]	-	-	-	-	-	-	-	-	1	10	ug/L	-	-	-
2,4- Dinitrophenol	SW3510B/SW8270B	Fixed-Base [b]	-	-	-	-	-	-	-	-	5	50	ug/L	-	-	-
1,1,1-Trichloroethane	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.08	0.8	ug/L	-	-	-
1,1,2-Trichloroethane	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.1	1	ug/L	-	-	-
1,4-Dichlorobenzene	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.03	0.3	ug/L	-	-	-
Chloroform	SW5030A/SW8260A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.03	0.3	ug/L	-	-	-
Cadmium	SW3020A/SW7131A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.0001	0.001	ug/L	-	-	-
Manganese	SW3005A/SW6010A	Fixed-Base [b]	-	-	-	-	-	-	-	-	0.002	0.02	ug/L	-	-	-
Aliphatic/Aromatic Acids	RSKSOP-177	Fixed-Base [b]	-	-	-	-	-	-	-	-	5	10	ug/L	-	-	-

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TABLE 4.1
ANALYTICAL METHODS AND REPORTING LIMITS
LANDFILL B PHASE III RAP/PHASE IV RIP WORKPLAN
WESTOVER ARB, MASSACHUSETTS

Targeted Analyte by Matrix	Analytical Method	Field or Fixed-Base	Soil Gas MDL [a]	Soil Gas Units	Site-Specific Soil MDL	Soil Reporting Limit	Soil Units	Site-Specific Sediment MDL	Sediment Reporting Limit	Sediment Units	Site-Specific Groundwater MDL	Groundwater Reporting Limit	Groundwater Units	Site-Specific SurfaceWater MDL	SurfaceWater Reporting Limit	Surface Water Units
SOIL GAS																
Methane	EPA TO-14	Fixed-Base [b]	0.01	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
1,1- Dichloroethane[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl Chloride[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
Methylene Chloride[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2-Trichloroethane[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform[f]	EPA TO-14	Fixed-Base [b]	0.5	ppbv	-	-	-	-	-	-	-	-	-	-	-	-
SOIL																
Total Organic Carbon[f]	CO2COUL	Fixed-Base [b]	-	-	.05 - .09	.05 - .09	%	-	-	-	-	-	-	-	-	-
Total Inorganic Carbon[f]	RSKSOP-102	Fixed-Base [b]	-	-	.05 - .09	.05 - .09	%	-	-	-	-	-	-	-	-	-
1,1- Dichloroethane[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0002	0.002	mg/kg	-	-	-	-	-	-	-	-	-
Vinyl Chloride[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0009	0.009	mg/kg	-	-	-	-	-	-	-	-	-
bis(2-Ethylhexyl)phthalate[f]	SW3550A/SW8270B	Fixed-Base [b]	-	-	0.07	0.7	mg/kg	-	-	-	-	-	-	-	-	-
Methylene Chloride[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0002	0.002	mg/kg	-	-	-	-	-	-	-	-	-
2- Chlorophenol[f]	SW3510B/SW8270B	Fixed-Base [b]	-	-	0.03	0.3	mg/kg	-	-	-	-	-	-	-	-	-
2,4- Dichlorophenol[f]	SW3550A/SW8270B	Fixed-Base [b]	-	-	0.03	0.3	mg/kg	-	-	-	-	-	-	-	-	-
2,4,6- Trichlorophenol[f]	SW3550A/SW8270B	Fixed-Base [b]	-	-	0.03	0.3	mg/kg	-	-	-	-	-	-	-	-	-
2,4- Dinitrophenol[f]	SW3550A/SW8270B	Fixed-Base [b]	-	-	0.33	3.3	mg/kg	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0004	0.004	mg/kg	-	-	-	-	-	-	-	-	-
1,1,2-Trichloroethane[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0005	0.005	mg/kg	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0002	0.002	mg/kg	-	-	-	-	-	-	-	-	-
Chloroform[f]	SW5030A/SW8260A	Fixed-Base [b]	-	-	0.0002	0.002	mg/kg	-	-	-	-	-	-	-	-	-
Cadmium[f]	SW3050A/SW7131A	Fixed-Base [b]	-	-	0.01	0.1	mg/kg	-	-	-	-	-	-	-	-	-
Manganese[f]	SW3050A/SW6010A	Fixed-Base [b]	-	-	0.2	2	mg/kg	-	-	-	-	-	-	-	-	-

[a] MDL = method detection limit
[b] Analysis performed by USEPA National Risk Management Research Laboratory in Ada, Oklahoma
[c] Dash (-) = not applicable
[d] mg/L = milligrams per liter
[e] ug/L = micrograms per liter
[f] not identified as soil gas COPCs; will only be measured at select sampling points to assess the potential for subsurface chemical sources.

4.2 SAMPLING STRATEGY

The proposed site characterization activities are designed to use a progressive, observational approach for the acquisition of data of sufficient quality to support risk assessment objectives and to evaluate a range of possible remedial/closure options. The sampling activities are built around a flexible, "real-time" analysis of data to guide subsequent field activities. Real-time analysis allows decisions to be made in the field while data are being collected in order to direct subsequent data acquisition in an effective and efficient manner. Existing data and the proposed field analyses will be used to guide the placement and sampling of additional soil borings and monitoring wells.

Field investigation efforts will be completed in the following sequence: (1) groundwater and soil gas screening in the landfill, (2) soil gas sampling for compound-specific analysis, (3) Geoprobe® soil sampling and groundwater monitoring point installation (from the least to the most contaminated areas), (4) groundwater monitoring point development, (5) collection of surface water, sediment, and groundwater samples for laboratory analyses (from least to most contaminated areas), (6) measurement of field water quality parameters in groundwater and surface water (sampling and measurement will be conducted from least to most contaminated areas), (7) aquifer slug tests, (8) surface water flow measurements. Several of these activities may be conducted concurrently at the discretion of the Parsons ES site manager to expedite the field work. However, care must be taken to minimize cross-contamination and other matrix-specific effects that might compromise data quality or complicate data evaluation. Appendix A is a site-specific SAP. Specific procedures and protocols for each field activity, including QA requirements, are presented in this appendix.

4.2.1 Site Access

Landfill B is easily accessed by primary base roads. Much of the former landfill is wooded, with sparsely vegetated areas associated with former landfill activities. Sampling locations within the forested area may require use of a hand auger or other

hand-driven sampling devices. The remaining sampling locations will be installed with a pickup truck-mounted Geoprobe®.

4.2.2 Landfill Soil Gas and Groundwater Field Screening

In-situ field screening for specific conductance, temperature, redox, DO, and total VOCs analysis will be conducted within the 13 acre landfill area. Screening activities will include single point screening of soil gas and groundwater. Total VOCs in groundwater will be semi-quantified using a field gas chromatograph. Soil gas will be screened for total volatile hydrocarbons, methane, oxygen, and carbon dioxide. Screening of soil gas and groundwater in the field will allow more effective placement of additional groundwater monitoring points and should identify any previously unknown sources of contamination. Screening activities will be conducted using hand-driven or Geoprobe® well point sampling and installation methods as described in the SAP (Appendix A). A maximum of 50 soil gas and 50 groundwater samples will be collected during the field screening process. Sampling locations are proposed on a 100-foot by 100-foot grid across the landfill. Locations of where previous geophysical survey anomalies have been identified will be sampled as appropriate to determine if the anomalies correspond to areas of potential groundwater contamination. The screening results will be used to compare various remedial/closure options, develop conceptual designs, and establish basic design criteria for a statistical groundwater monitoring plan for the Landfill B site.

Soil gas and groundwater screening points will be installed at the selected locations using a mechanically driven sampling device. Manual drive point sampling will be used in place of the Geoprobe® at locations where vehicle access is limited by terrain or vegetation. A soil gas screening point consists of a stainless steel drive point attached to a piston rod contained within a stainless steel piston holder. A 0.25-inch threaded sampling port is located at the top of the piston holder. The assembly remains closed as the sampling point is advanced into the subsurface. After being driven to the specified sample depth, the piston holder and drive rods are retracted approximately 6

inches and a void space is created in-between the drive point and the piston holder. Teflon® tubing is then attached to a piston holder connector, which is then inserted though the center of the drive rods and treaded into the sampling port. A clean rubber washer on the treaded portion of the connector is used to seal the void space. A small vacuum pump is used to purge and collect a soil gas sample from the void space. After sampling, the drive rods and soil gas sampling assembly will be decontaminated according to procedures outlined in the SAP (Appendix A).

A groundwater screening point will consist of a 2-foot long, 0.5-inch diameter, 0.01-inch slotted drive rod attached to a stainless steel drive point. The slotted groundwater sampling rod will be advanced approximately 4 feet into the shallow groundwater. The depth to groundwater will be measured and high density polyethylene (HDPE) tubing will be inserted down the center of the drive rods to below the groundwater surface. Groundwater samples will be extracted using a peristaltic pump and a flow-through sampling cell. The small vacuum produced by the pump for groundwater screening is not expected to affect the target analytes. Screening point installation, sampling, and decontamination procedures are included in the SAP (Appendix A). Permanent groundwater monitoring wells will be installed, as necessary, during Phase IV implementation.

4.2.3 Soil Gas Sampling

Permanent soil gas sampling points will be installed in the vadose zone at selected locations using manual or mechanical sampling devices as described in the previous section. A permanent soil gas point will consist of an sacrificial, stainless steel drive tip equipped with a stainless steal mesh screen and Teflon® tubing extended to the surface. The drive sampling device pushes the well point to the target depth where the screened portion is left in place once the rods are removed. Teflon® tubing will be attached to the expendable tip prior to placing the point. Teflon® tubing is recommended to minimize the potential for oxygen diffusion into or out of the soil gas sample during sampling.

Soil gas sampling for laboratory analysis will the be completed to determine the potential for lateral and upward diffusion of soil contamination in the soil-pore vapors and to assess the presence of elevated methane vapors. Up to eight soil gas samples will be withdrawn from permanent soil gas points proposed to be installed based on the results of the soil gas field screening. Soil gas sampling procedures are included in the SAP (Appendix A). Soil gas samples from these permanent points will be screened for total fuel hydrocarbons, oxygen, and carbon dioxide; and analyzed for methane and other select VOCs. The soil gas probes are expected to be installed in the most contaminated areas of the landfill as determined by the soil gas screening. Soil gas samples will be analyzed as described in Table 4.1. Soil gas sampling will be conducted by qualified Parsons ES personnel who have thoroughly reviewed the work plan, including Appendix A, prior to sample acquisition and will have a copy available onsite for reference.

4.2.4 Soil Sampling

Soil sampling will be necessary to determine the total organic carbon (TOC) content of the aquifer matrix upgradient from the landfill and to establish the physical and chemical characteristics of the saturated solid matrix within and directly beneath the landfill. First, borehole will be installed and sampled at an upgradient location west of the landfill. A groundwater monitoring point will be installed at this location as indicated on Figure 4.1. Presumed background soil samples, collected using a Geoprobe® driven sampler, will be carefully evaluated to determine the stratigraphy of the sample location and presence of any measurable or visible contamination, sampled for laboratory analyses, and then composited for headspace readings. Two soil samples will be taken from this background borehole, one will be collected at the top of the capillary fringe, and one will be collected approximately 40 feet below the groundwater surface. Background soil samples will be analyzed for TOC as prescribed in Table 4.1. The background soil sampling location was selected to provide additional information about background stratigraphy and background TOC concentrations.

Additional soil samples will be collected within the landfill property for chemical analysis. These site soil sampling locations will be selected based on groundwater and soil gas screening results (i.e., at permanent soil gas monitoring points). Soil samples will be examined by the field geologist to determine the subsurface stratigraphy of landfill material and the vertical depth of any measurable, olfactory, or visible contamination. Soil cores samples initially will be screened for organic vapors using field instruments and a headspace procedure to determine the relative VOC contamination. Discrete samples showing the highest relative contamination by field organic vapor headspace analyses will be submitted for laboratory analysis from the intervals that appear most contaminated both above and below the water table surface. Soil samples will be analyzed for water matrix COPCs described in Table 4.1. Sampling procedures are presented in the SAP (Appendix A).

Soil sampling during soil gas monitoring point installation will be conducted by qualified Parsons ES personnel under the direction of a MADEP LSP. In addition, sampling personnel will have thoroughly reviewed this work plan, including Appendix A, prior to sample acquisition and will have a copy available onsite for reference.

4.2.5 Groundwater Monitoring Point Construction and Development

A maximum of 17 groundwater monitoring points will be installed at this site as part of this proposed effort. A minimum of 14 of these points will be installed as seven nested pairs at the landfill perimeter with screened intervals near the groundwater surface and approximately 40-50 feet below the groundwater surface to define the vertical extent of contamination. Three shallow monitoring points will be installed within the landfill at selected groundwater grab sampling locations depending on field screening results. The proposed nested monitoring point locations are shown on Figure 4.1. The proposed locations in the landfill are dependent the results of the field groundwater screening.

Groundwater monitoring points will be installed using either mechanical or manual equipment. The groundwater monitoring points will be constructed through the Geoprobe® drive rods using three 0.75-inch-diameter, flush-threaded, Schedule 40 polyvinyl chloride (PVC) well casings and screens. The screens will consist of 5-foot-long sections of 0.010-inch factory-slotted screen with bottom caps positioned with 4 feet extending below the water table for shallow points. The top of the casing will be sealed with a 1/2 PVC slip cap. The surface completion will consist of an 8-inch-diameter, flush-mounted well box set in a concrete collar sloping away from the well box and matching the site grade.

Monitoring point clusters will consist of two points screened at a shallow depth about 4 feet below the top of the water table, and at a deep depth with the well screen placed at a depth between 40 and 50 feet below the groundwater surface. These points will be used to assess the vertical extent of potential groundwater contamination and vertical gradients at the site. The monitoring point clusters are proposed to be installed only around the perimeter of the Landfill. Well point installation procedures are included in the SAP (Appendix A). Installation of permanent 2-inch monitoring wells that will be used in any post-closure assessment and monitoring activities will be considered and planned for in the Phase IV RIP.

Prior to collecting groundwater samples, all new monitoring points will be developed using the procedures presented in the SAP (Appendix A). Well development will continue until a minimum of 10 casing-volumes of water have been removed from the wells and the pH, conductivity, and temperature do not fluctuate by more than 10 percent over one casing volume. Following development, all of the monitoring points will be allowed to return to static water level before collecting groundwater samples.

4.2.6 Groundwater Sampling

Up to 23 existing monitoring wells and all newly installed groundwater monitoring points will be sampled to support preparation of the Phase II RAP/Phase IV RIP. Prior

to sampling, each sampling location will be purged by removing a minimum of three casing volumes of water. Micropurging techniques described in the SAP will be used for newly installed groundwater monitoring points. Groundwater samples for non-VOC analysis will be collected using a peristaltic pump and a flow through cell sampling device. Samples for VOC analysis will be collected using bailers to eliminate any possible vacuum problems caused by peristaltic pumps. Groundwater samples collected during this field investigation will be analyzed for COPC and geochemical parameters according to the methods listed in Table 4.1.

All screening and laboratory analytical results will be used to further delineate the areal extent of the dissolved COPCs, and to evaluate the potential effectiveness of natural chemical attenuation processes. Existing groundwater monitoring wells (Figure 4.1) and newly installed monitoring points will be used to characterize physical hydrogeologic conditions such as depth to groundwater, groundwater flow directions, and hydraulic gradients. The extent of any residual contamination that may act as a continuing source of contamination to other media (e.g., sediments) also will be determined during the site investigation. Data from previous investigations will be incorporated into the final analysis to the extent practicable to avoid unnecessary duplication of field results and to evaluate the change in contaminant concentrations over time.

4.2.7 Aquifer Testing

Slug tests will be performed in each of the exiting monitoring well pairs B-2/2A, B-5/5A, B-7/7A, B-10/10A, B-13/13A, and B-18/18A (Figure 4.1). Slug tests will be performed to determine the hydraulic conductivity of the upper and lower portions of the shallow aquifer at well locations along the landfill perimeter and parallel to the groundwater flow direction. These field tests are necessary to support quantitative groundwater flow and contaminant transport analyses.

4.2.8 Surface Water Sampling

Surface water quality samples will be collected to ascertain whether any exposure pathways involving surface water could be complete and what, if any, surface water controls may be necessary as part of the proposed remedial/closure option. Surface water flow out of the landfill may transport landfill related contaminants into the Westover ARB storm drainage system, which eventually discharges into Stony Brook approximately 1,800 feet east of the site. Several chlorinated compounds have previously been detected in surface water samples collected from the drainage swale located near the south central portion of the landfill at concentrations above identified comparison criteria (Figure 2.2; Table 2.5).

Three surface water samples will be collected at the locations proposed as shown on Figure 4.1. A surface water sample will be collected from the wetland located north of the railroad track, approximately 150 feet across from monitoring well B-3, to determine if groundwater contamination associated with the landfill is discharging at measurable concentrations into this area. The remaining two surface water samples will be collected in the drainage swale south of the landfill. The samples will be collected immediately downgradient of the landfill and at the storm drain inlet approximately 1,000 feet south from the landfill. These surface water samples will determine the nature and extent of surface water contamination discharging from the landfill and will help establish attenuation rates. Surface water sampling procedures are presented in the SAP (Appendix A).

4.2.9 Sediment Sampling

Sediment samples will be collected at the same locations as surface water samples. Samples will be collected from the upper six inches of sediment at each location and analyzed to determine if cadmium contamination detected in a previous sampling event represents a significant problem. Sediment sampling procedures are presented in the SAP (Appendix A).

4.3 SUMMARY OF SAMPLING CHRONOLOGY

Field sampling should progress through the following steps to maximize the results of the screening data and the selection of permanent sampling locations for soil gas, soil, groundwater, surface water, and sediments.

- Layout of landfill source area sampling grid;
- Collection of one soil gas and one shallow groundwater sample from each grid point. Field analysis of samples for VOCs using on-site gas chromatograph;
- Soil sampling during installation of permanent soil gas monitoring points;
- Installation and sampling of permanent soil gas monitoring points;
- Groundwater monitoring point installation in order from the least to the most contaminated areas using a Geoprobe®;
- Groundwater monitoring point development;
- Collection of groundwater samples from least to most contaminated areas for laboratory analysis and measurement of field water quality parameters;
- Aquifer slug tests;
- Surface water flow and sample collection for field and laboratory analysis; and
- Sediment sampling for laboratory analysis.

SECTION 5

PREPARATION OF A FOCUSED PHASE III RAP

Upon completion of the field work described in Section 4, a focused Phase III RAP will be developed in accordance with the requirements of 310 CMR 40.0861. As noted in Section 1, the proposed Phase III RAP also will satisfy the substantive requirements of a landfill CAAA for a solid waste management facility, as described at 310 CMR 19.150(6). A Phase III FS, which concludes with a preliminary RAP, has been prepared by OBG (1996b). That document recommends, as a temporary remedial/closure option, that a cover system design that differs from the standard cover requirements specified at 310 CMR 19.112 be installed at Landfill B. The Phase III FS also recommends reliance on natural chemical attenuation processes in lieu of a standard groundwater protection system, as described at 310 CMR 19.110. Both of these alternate remedial concepts have been conditionally accepted by MADEQ as appropriate remedial/closure strategies for Landfill B, pending a more quantitative "equivalency" demonstration.

The purpose of the additional field work and Phase III data analysis described in this work plan is to address several unresolved questions regarding the presence of potential primary and secondary chemical sources within the landfill, and to develop a quantitative comparative analysis of various remedial/closure options. The focused Phase III RAP is intended to provide sufficient evidence that the two alternate remedial/closure technologies proposed in the Phase III FS (OBG, 1996b) will provide an "equivalent" level of protection as that afforded by standard remedial/closure approaches. Additionally, these data are required to facilitate conceptual design of various components of the proposed remedial/closure strategy, including development

of design and assessment criteria for natural chemical attenuation. Data collected under this work plan also will facilitate preparation of a partial Phase IV RIP (which will be comparable to a closure/post-closure plan, as defined at 310 CMR 19.140). The elements of these documents that may be completed as part of the proposed effort are further described in Section 6 of this work plan.

5.1 RAP OBJECTIVES

The primary objective of the Phase III RAP will be to obtain MADEQ and public approval of a comprehensive closure plan for Landfill B that satisfies relevant requirements of both 310 CMR 19.000 and 310 CMR 40.0000; is protective of potential receptors and environmental resources; and is cost effective. Consequently, as noted in Section 1, the Phase III RAP needs to present documentation sufficient to:

- Support selection, approval, and conceptual design of an alternate cover system that provides an "equivalent" level of protection as a standard approach, pursuant to 310 CMR 19.113;

- Demonstrate quantitatively that natural chemical attenuation processes are expected to be sufficient to contain, and possibly destroy/detoxify, groundwater (and water surface) contamination so that this alternate groundwater protection system may be selected and approved, contingent upon satisfying the requirements of an applicable RAO at least outside the boundary of the landfill;

- Evaluate and select the most cost-effective remedial/closure option for addressing any potentially unacceptable hazards or health risks associated with landfill gases (e.g., methane) and surface water and sediment contamination; and

- Assess the potential for ecological receptor exposure to site-specific chemical contamination.

To accomplish these objectives, the Phase III RAP will:

- Summarize existing and new site characterization data;

- Better define the relationship between the source of contamination (landfill waste) and groundwater plume formation and migration potential;

- Quantitatively evaluate the performance of alternate cover system designs in relationship to both the no-action alternative and a standard final cover system;

- Quantitatively evaluate the performance of natural chemical attenuation processes at minimizing leachate generation and migration of dissolved contamination in relation to a standard groundwater protection system design using state-of-the-art sampling and data evaluation techniques;

- Investigate the need to supplement these two remedial/closure options with additional remedial/closure components to satisfy the requirements of 310 CMR 19.140;

- Evaluate exposures of and risks to ecological receptors potentially exposed to media affected by landfill wastes;

- Document that the proposed remedial/closure approach will maintain the current No Significant Risk level, upon implementation of required AULs, and meet the qualitative objectives an applicable RAO at the perimeter of and downgradient from the landfill property; and

- Establish risk-based concentration goals that can be integrated into closure/post-closure assessment and monitoring plans to track progress toward a permanent solution.

5.2 MAJOR COMPONENTS OF THE FOCUSED REMEDIAL ACTION PLAN

The Phase III RAP will be a technical supplement to the existing Phase III FS (OBG, 1996b) so that all substantive, relevant requirements of 310 CMR 19.000 and

40.0000 are satisfied. The Phase III RAP will include detailed information on field and laboratory analytical results; quantitative source, release, fate, and transport analyses for different remedial/closure options; updated receptor exposure pathways analyses, as necessary, for each remedial/closure option; estimated exposure-point concentrations; updated human health, safety, and ecological risk characterization information for the proposed remedial/closure approach; updated and more detailed comparative evaluation of different remedial/closure options using the criteria specified at 310 CMR 19.150(6), 310 CMR 40.0858, and MADEP (1993) technical guidance; identification of an applicable RAO; and development of matrix-specific, chemical-specific, risk-based concentration goals to be incorporated into the Phase IV RIP and closure assessment and monitoring plans.

5.2.1 Data Presentation

The RAP will be structured to clearly and concisely present the approach and results of each of the major steps completed to evaluate and select an appropriate remedial alternative for the site. The RAP will be structured to place emphasis on better defining the migration of contaminated groundwater using additional site characterization data, the role of natural attenuation as a permanent method of contaminant destruction, potential source reduction techniques, and remedial alternative evaluation and selection. Detailed information on the methodologies used in each of these steps will be contained in appendices to the RAP. This approach should streamline the final report to focus on the results of the evaluation. In this way, regulators and other decision-makers will not have excessive documentation to review to determine whether the recommended remedial alternative meets the stated objectives of the project and MADEQ requirements.

5.2.2 Data Evaluation and Modeling

Field data to be used in quantitative fate and transport analyses will be gathered and sorted by environmental medium. Any analytical data used in this project will be

evaluated in terms of their quality. This data usability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The data evaluation methods defined by USEPA (1989 and 1992a) in OSWER Directive 9285.7-01a, *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (EPA/540/1-89/002), and OSWER Directive 9285.7-09a, *Guidance for Data Usability in Risk Assessment* will be used. By using the analytical methods and quantitation limits defined in this work plan (see Table 4.1), the data collected during the field work phase of this project are designed to satisfy the rigorous data requirements of quantitative fate and transport modeling and risk analysis.

Data may be used as input parameters to the various quantitative models discussed in Sections 3.2 and 3.3. Sample models which require a single-point concentration value (e.g., air dispersion) will use exposure-point concentrations developed using either the USEPA (1992b) *Supplemental Guidance to RAGS: Calculating the Concentration Term* (Publication 9285.7-081) or an equally defensible method (e.g., a probabilistic density function of site characterization data). The exposure-point concentration term will be derived to represent the highest exposure that could reasonably be expected to occur for a given reasonable maximum exposure duration. This value is intended to account for both the uncertainty in environmental data and the variability in exposure parameters. More complex models such as the USGS MOC do not require single-point values. In these cases, unadjusted field data will be used to simulate the fate and transport of contamination in the target environmental medium.

5.2.3 Method of Risk Characterization

Additional risk characterization will only be completed as part of the Phase III RAP to verify the finding of No Significant Risk presented in the Phase II supplemental RI (OBG, 1996a). A comparative evaluation of the expected protectiveness of each of the various remedial/closure options considered in the detailed evaluation in the Phase III

RAP also will be completed. The risk characterization activities conducted in support of the Phase III RAP will be consistent with a Method 3 risk characterization (310 CMR 40.0990). Method 3 relies upon detailed information about the site, the nature of chemical contamination, and the potential exposure of human and ecological receptors under all current and reasonably foreseeable site activities. A Method 3 risk characterization is performed in a manner consistent with scientifically acceptable risk assessment practices, and considers guidance published by both MADEP and the USEPA. Consequently, the methods of risk characterization that could be employed as part of the Phase III evaluation will be generally consistent with the risk assessment methods described in RAGS, Volume I (USEPA, 1989) and ecological risk assessment guidance (USEPA, 1996), and analogous to those used to evaluate long-term risks associated with various remedial alternatives. Additionally, potential risks to public welfare and safety will be assessed as prescribed in 310 CMR 40.0994 and 310 CMR 40.0960, respectively.

It is important to note that the Air Force will improve upon traditional approaches to characterizing risks, as necessary, by using advanced tools of risk assessment (e.g., probabilistic characterizations of exposure-point concentrations, exposure assumptions, and resulting risk estimates). Such evaluations will only be prepared if this information is needed to accurately compare risk reduction benefits versus remediation/closure costs.

5.2.3.1 Exposure Pathway Evaluation

As described in Section 3, an exposure assessment identifies the potential human and ecological receptors that could come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a mechanism of release and transport, a receptor, and a route through which the contamination could reach the receptor. The Phase III RAP will present the results of state-of-the-art techniques and

models that can be used to predict the long-term effectiveness of various landfill cover options and natural chemical attenuation processes. The CSM presented in Section 3 of this work plan identifies potential chemical sources, known release and transport mechanisms, current and potential future receptors, and exposure routes that may be involved in current or future land-use scenarios for the site. This CSM was developed to ensure that adequate data are collected to support a quantitative evaluation of the potential for exposure pathway completion at the site.

Field data and model simulations which account for the physical setting and characteristics of the site will be used to estimate whether any exposure pathway is completed and, if so, to quantify COPC concentrations at the point of exposure. The Phase III risk characterization will support development of chemical-specific concentration goals for each affected environmental medium.

5.2.3.2 Identifying Cleanup Goals

In the event that measured concentrations of COPCs exceed MADEQ or USEPA promulgated standards that are appropriate for Landfill B, site-specific concentration goals will be developed. The objective of developing these concentration goals is to provide a mechanism to assess the long-term protectiveness of the implemented remedial/closure strategy. All applicable or suitably analogous health standards will be initially considered as risk-based concentration goals. Examples of such standards are listed at 310 CMR 40.0993(3). In the event these standards are deemed not applicable or suitably analogous, Method 3 risk characterization techniques will be used to "back calculate" protective concentration levels. These techniques are consistent with USEPA (1991) guidance on establishing remedial goals. The Air Force anticipates, at this point, that GW-2 standards and S-2 standards will provide the level of protection desired at and downgradient from Landfill B for groundwater and soils, respectively. If appropriate risk-based concentration goals will be adjusted to ensure protection of ecological receptors from exposure to toxic chemicals in affected media.

5.2.4 Selection of Preferred Remedial/Closure Approach

The Phase III RAP will support the selection and approval of a remedial/closure approach for Landfill B by providing information of sufficient detail on the process by which the recommended strategy was developed and evaluated.

5.2.4.1 Previous Screening of Various Remedial/Closure Options

The Phase III FS (OBG, 1996b) includes a preliminary evaluation of several landfill cover, groundwater treatment, and removal technologies that could be considered for application at Landfill B. These various technologies were grouped into several remedial/closure options, including:

Soil/Fill Source Reduction Alternatives

- Alternative A - No Action;
- Alternative B - Capping in full compliance with 310 CMR 19.112 standards;
- Alternative C - The proposed Phase III FS (OBG, 1996b) landfill cover (Alternative Design per 310 CMR 19.113); and
- Alternative D - Removal and Relocation of Landfill Waste.

Groundwater Alternatives

- Alternative A - No Action;
- Alternative B - Natural Chemical Attenuation with Long-Term Monitoring; and
- Alternative C - Groundwater Extraction and Treatment.

Each remedial/closure option was qualitatively evaluated using the following 310 CMR 40.086 criteria: effectiveness, short and long-term reliability, implementation, cost, risks, benefits, timeliness and non-pecuniary interests such as aesthetics. Based

on this evaluation, Alternative C (Improved Landfill Cover) and Alternative B (Natural Attenuation) were selected and recommended for Landfill B. Westover ARB has recommended to MADEQ that the conclusions of the Phase III FS be accepted on the condition that a more focused evaluation of the selected remedy be completed as part of the Phase III RAP to scientifically document the anticipated effectiveness of natural chemical attenuation processes and to demonstrate the sufficiency of an improved landfill cover to meet the equivalency requirements described at 310 CMR 19.113.

5.2.4.2 Focused Remedial Evaluation

The Phase III FS (OBG, 1996b) fails to provide the "sufficient detail" required to gain Air Force, regulatory, and public acceptance of the proposed alternate landfill cover/natural attenuation remedial/closure strategy for Landfill B. As such, the field work and Phase III evaluation proposed in this work plan will focus the remedial evaluation on obtaining data to answer six key questions:

1. Has the groundwater plume migration been adequately defined to ensure that there is no potential risk of off-base migration?

2. Can the source(s) of contamination be more accurately defined at this 13-acre landfill site, and are any such sources amenable to cost-effective removal options?

3. How is the landfill waste interacting with the groundwater, and how will various cover options impact future leaching?

4. How effective has natural chemical attenuation been at containing groundwater contamination, and at what rate can natural attenuation be expected to destroy/detoxify a continuing source of contamination?

5. Have landfill wastes affected downstream surface water and/or sediment to such an extent that there are unacceptable exposure risks for receptors exposed to these media?

6. What combination of landfill cover design and long-term monitoring of natural chemical attenuation will best satisfy the remedial action evaluation criteria of 310 CMR 40.086 and landfill closure requirements of 310 CMR 19.140?

The focused Phase III evaluation and final selection of a remedial action for Landfill B will clearly address each of these questions and present the recommended actions in the format specified by 310 CMR 40. 086.

5.2.4.3 Feasibility of Permanent Vs Temporary Solutions

In accordance with 310 CMR 40.0861, a permanent solution is preferred whenever feasible. The feasibility of achieving background concentrations must be evaluated in the Phase III RAP. Given that total removal of all landfill material is an unlikely solution, Landfill B is not likely to be restored to background conditions. A temporary solution is generally the only solution at large landfill facilities. However, it may be possible to demonstrate that natural chemical attenuation processes are capable of destroying contaminants within a zone of compliance established around the site. In this case, the quality of groundwater and surface water leaving the zone of compliance may approach or equal background water quality. The Phase III RAP will describe this potential for a permanent solution.

5.2.4.4 Compliance With Solid Waste Regulation 310 CMR 19.140

In addition to complying with RAP requirements set forth in the MCP, the preferred remedy identified in the Phase III RAP must also be sufficient to satisfy the substantive landfill closure requirements at 310 CMR 19.140. The general performance standards for landfill final cover and groundwater protection system designs are described in

Section 3 of this work plan. For proper closure, the landfill owner must also provide groundwater, surface water, and landfill gas monitoring systems. Specific requirements for groundwater monitoring well locations and construction are included in 310 CMR 19.118. It appears that the existing multi-depth monitoring wells around Landfill B may meet these requirements. Surface water sampling points must also be established to demonstrate that landfill leachate is not adversely impacting local surface waters and permanent soil gas monitoring points must be established and regularly monitored to determine if landfill gases are migrating beyond the boundaries of the landfill. All of these monitoring requirements will be addressed for the preferred remedial/closure option for the site and presented in detail in the partial Phase IV RIP, which is described in Section 6 of this work plan.

SECTION 6

DEVELOPMENT OF A PHASE IV RIP

The purpose of the Phase IV RIP is to provide a clear description of remedial/closure responsibilities, an implementation plan for the approved remedial/closure strategy, and required post-closure maintenance, monitoring, and assessment plans to track and verify effective performance. If an alternate cover system design is selected and approved as part of the Phase III evaluation process, the proposed partial Phase IV RIP will present a conceptual design of the landfill cover component. A complete engineering design, as described in 310 CMR 40.0874 and required for a final closure/post-closure plan pursuant to 310 CMR 19.140, will not be completed under the current scope of this contract. Additionally, if natural chemical attenuation is selected and approved for implementation as the alternate groundwater protection approach for Landfill B, the partial Phase IV RIP to be prepared as part of this effort will include basic design criteria to be included in post-closure monitoring plans. Similar to the detailed cover specifications, final post-closure maintenance, monitoring, and assessment plans will not be developed as part of this effort unless additional funding is made available.

6.1 DESIGN CRITERIA FOR NATURAL CHEMICAL ATTENUATION

If the Phase III evaluation confirms that natural chemical attenuation processes are sufficient to achieve an "equivalent" level of protection, basic design criteria for monitoring the long-term progress toward a permanent solution will be developed. These design criteria will include the location of confirmation, sentry, and point-of-compliance (POC) monitoring wells; the sampling and analytical requirements; and

desired data evaluation techniques to develop a statistically-defensible assessment of site conditions over time.

Confirmation wells will be located within the plume and immediately downgradient (i.e., within 1 or 2 years travel distance) from the existing plume and will provide for early confirmation of model and engineering predictions. The POC wells will be located further downgradient (e.g., near the property boundary; approximately 5 years downgradient from the existing plume; 1 or 2 years upgradient from the nearest potential groundwater receptor). The exact location of POC wells will be established in concert with regulatory authorities to meet the monitoring requirements set forth in MADEP (1993) technical guidance on landfill closure. At a minimum, the wells likely to be included in any monitoring plan will be located upgradient from the landfill, possibly within the landfill (providing cap disruption can be avoided), at the perimeter of the landfill, and downgradient from the established perimeter. The sampling frequency of the well networks will depend on their exact location, compliance documentation requirements, and other regulatory considerations.

Design criteria in the form of recommended data analysis techniques also will be compiled for the Phase IV RIP. Analytical sampling data collected as part of post-closure monitoring and assessment activities will need to be used to track the progress of natural chemical attenuation. Data analysis techniques used in the Phase III evaluation will be adapted for inclusion in the Phase IV RIP. Additionally, the recommended data evaluation techniques will be based on a statistically-valid sampling and analysis program designed to monitor progress toward a permanent solution. Consequently, the Phase IV RIP will identify desired monitoring locations, summarize chemical analytical requirements, and present data evaluation methods to be used as part of any ongoing assessment activities.

If quantitative data analysis indicates that natural chemical attenuation processes alone will be insufficient to provide an "equivalent" level of protection, these processes

may have to be supplemented with another remedial/closure option such as groundwater pump-and-treat or targeted source removal. The impact of different remedial/closure options that may be needed to supplement natural chemical attenuation will be evaluated quantitatively in the Phase III RAP.

6.2 REQUIRED ACTIVITY AND USE LIMITATIONS

Regardless of the selected remedial/closure strategy, some form of land and/or groundwater AULs will need to be established, pursuant to the assumptions included in the updated 1996 BRA (OBG, 1996a). Because the entire landfill and the groundwater plume originating in the landfill are located on Westover ARB property, which is designated for airfield/open space use, certain land use controls already are in place. The Phase IV RIP will identify the specific area that should be designated for AULs, specify the type of controls required, and suggest criteria for determining when controls may no longer be needed. The recommendation included in the partial Phase IV RIP will be subject to regulatory and public approval.

SECTION 7

PROPOSED PROJECT SCHEDULE

The schedule presented as Figure 7.1 details the proposed duration and date of completion for each of the major tasks involved in evaluating, selecting, designing, and implementing a remedial/closure alternative for the Landfill B site in compliance with MADEP (1993) guidance and using the risk-based approach to remediation described in this work plan. Each of these major tasks is described in detail in previous sections of the work plan.

SECTION 8

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APPENDIX A

SAMPLING AND ANALYSIS PLAN

SITE SAMPLING AND ANALYSIS PLAN

FOR

REMEDIAL ACTION PLAN AND LONG-TERM MONITORING PLAN

RISK-BASED APPROACH TO REMEDIATION

LANDFILL B, WESTOVER ARB, MASSACHUSETTS

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION

BROOKS AIR FORCE BASE, TEXAS 78235-5000

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SECTION 1

INTRODUCTION AND DATA QUALITY OBJECTIVES

1.1 INTRODUCTION

The purpose of this site-specific sampling and analysis plan (SAP) is to describe the procedures to be followed when collecting data in support of site characterization and the long-term monitoring plan (LTMP) which will be completed as a part of the Remedial Implementation Plan for Landfill B at Westover ARB, MA. Details on analytical requirements, desired quantitation (detection) limits, and proposed sampling locations are identified within Section 4 of the Work Plan for Remedial Action Plan/Remedial Implementation Plan Development- Landfill B, Westover ARB, Massachusetts (Parsons ES, 1996). Specific quality assurance (QA) sampling requirements for the Landfill B site are summarized herein as part of the site-specific sampling procedures. These additional samples will be used to determine the precision, accuracy, completeness, and representativeness of the final data set.

The remainder of Section 1 discusses data quality objectives. Soil gas sampling is described in Section 2; procedures for soil and sediment sampling are presented in Section 3; groundwater/ surface water sampling procedures are described in Section 4; and field quality assurance/quality control (QA/QC) samples are described in Section 5. Section 6 describes field data reduction, validation, and reporting; Section 7 presents analytical procedures for groundwater/ surface water and soil/sediment sampling. References used in this SAP are listed in Section 8.

1.2 DATA QUALITY OBJECTIVES

The objectives of collecting and analyzing environmental samples are 1) to determine the three-dimensional distribution of hydrocarbon and heavy metal contamination at the site; 2) to obtain the data needed to evaluate the effectiveness of specific remedial approaches, including landfill covers and natural attenuation of groundwater; 3) to establish site-specific remediation goals that minimize or eliminate risk potential to receptors and limit offsite migration of site-related contamination; and 4) to prepare a remedial action plan and remedial implementation plan to progress toward a final site remedy. This section has been developed for use in conjunction with sampling activities to be undertaken at Landfill B, and describes the QA/QC procedures and protocols that will be used during sample analysis. This section will serve as a controlling mechanism during this investigation to ensure that a sufficient quantity of data is collected and that all data collected are valid, reliable, and defensible.

1.3 ANALYTICAL DATA QUALITY LEVELS

Data quality objectives (DQOs) for the analyses described herein are defined in the interim final guidance, *Data Quality Objectives Process for Superfund* (USEPA, 1993). The analytical levels for this project's DQOs will conform to the two USEPA-defined categories of data. These data categories are defined below (USEPA, 1993):

Screening Data with Definitive Confirmation - Screening data are generated by rapid, less precise methods of analysis with less rigorous sample preparation. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, instead of elaborate extraction/digestion and cleanup. Screening data provide analyte identification and quantification, although the quantification may be relatively imprecise. At least 10 percent of the screening data are confirmed using analytical methods, QA/QC procedures, and QC criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality. Results of field laboratory analyses conducted at the site will be considered screening-category data.

Definitive Data - Definitive data are generated using rigorous analytical methods, such as approved USEPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of hard-copy printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined. Results of fixed-based laboratory analyses of samples collected at the site will be considered definitive data.

During the AFCEE risk-based remediation program, the following data quality levels will be used as indicated:

- Screening analyses with definitive confirmation will be used for the air screening in worker breathing zones for health and safety purposes. This category may also be used to screen samples to select portions for further analysis. For example, soil gas or sample headspace may be screened to determine if laboratory analyses are required. In addition, this data category will be used to determine the presence of geochemical parameters that support natural attenuation of chlorinated hydrocarbon contaminants in groundwater. Resulting data will be used to evaluate the effectiveness of natural attenuation at the site.

- Definitive analyses will be used to satisfy the requirements for site characterization, risk analysis, decision document preparation, and site cleanup prioritization. USEPA Level III data from previous site investigations will be combined with newly acquired definitive data to evaluate the magnitude and extent of contamination at the site. Definitive data acquired during the investigation will be used to evaluate potential receptor risks and to develop remedial alternatives.

An effective QA program addresses DQOs for both field sampling and laboratory methodologies. The contractor's field QA efforts will focus on assuring that samples are representative of the conditions in the various environmental media at the time of sampling. Fixed-based laboratory QA efforts will be aimed primarily at assuring that

analytical procedures provide sufficient accuracy and precision to reliably quantify contaminant levels in environmental samples. The contract laboratory also will ensure that analyzed portions are representative of each sample, and that the results obtained from analysis of each sample are comparable to those obtained from analysis of other similar samples.

1.4 DATA QUALITY ASSESSMENT CRITERIA

Data assessment criteria will be used to evaluate the quality of both the field sampling and screening methods and laboratory performance for the project, and are expressed in terms of analytical precision, accuracy, representativeness, completeness, and comparability. Procedures used to assess data accuracy and precision are in accordance with *Guidelines Establishing Test Procedures for the Analyses of Pollutants,* Appendix III, "Example Quality Assurance and Quality Control Procedures for Organic Priority Pollutants" (40 CFR 136), and the respective analytical methods from the USEPA (1995) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846.*

1.4.1 Precision

Precision is the measure of variability among individual sample measurements under prescribed conditions. The results of laboratory control samples (LCS) demonstrate the precision of the methods. When the LCS results meet the accuracy criteria, (USEPA, 1995) results are believed to be precise. This is based on the LCS being within control limits in comparison to LCS results from previous analytical batches of similar methods and matrices. The relative percent difference (RPD) of field duplicate, laboratory sample duplicate, and matrix spike/matrix spike duplicates (MS/MSD) results demonstrate the precision of the sample matrix. Precision will be expressed in terms of RPD between the values resulting from duplicate analyses. RPD is calculated as follows:

$$RPD = [(x1 - x2)/X][100]$$

where:

$x1$ = analyte concentration in the primary sample

$x2$ = analyte concentration in the duplicate sample

X = average analyte concentration in the primary and the duplicate sample.

Acceptable levels of precision will vary according to the sample matrix, the specific analytical method, and the analytical concentration relative to the method detection limit (MDL). For field duplicate samples, the target RPDs are ≤ 35 percent for soil and water samples. Precision criteria for the laboratory QC samples are defined by limits listed in Table 1.1. An RPD within the control limit indicates satisfactory precision in a measurement system.

TABLE 1.1
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Aromatic Volatile Organic Compounds SW5030A/SW8020A (W[d], S[e])	1,2-Dichlorobenzene	61–134	≤ 20	51–144	≤ 30
	1,3-Dichlorobenzene	70–131	≤ 20	60–141	≤ 30
	1,4-Dichlorobenzene	75–126	≤ 20	66–136	≤ 30
	Benzene	75–125	≤ 20	66–135	≤ 30
	Chlorobenzene	75–129	≤ 20	66–139	≤ 30
	Ethylbenzene	71–129	≤ 20	61–139	≤ 30
	Toluene	70–125	≤ 20	60–135	≤ 30
	Xylenes, total	71–133	≤ 20	61–143	≤ 30
	Surrogates:				
	Bromochlorobenzene	46–136	NA[f]	36–146	NA
	Bromofluorobenzene	48–138	NA	38–148	NA
	Difluorobenzene	48–138	NA	38–148	NA
	Fluorobenzene	44–165	NA	34–175	NA
	1,1,1-Trifluorotoluene	44–165	NA	34–175	NA
Methane SW3810 Modified (W)	Methane	70-130	≤ 20	NA	NA
	Ethane	70–130	≤ 20	NA	NA
	Ethene	70–130	≤ 20	NA	NA
Volatile Organics SW5030A/SW8260A (W, S)	1,1,1,2-Tetrachloroethane	72–125	≤ 20	62–108	≤ 30
	1,1,1-Trichloroethane	75–125	≤ 20	65–135	≤ 30
	1,1,2,2-Tetrachloroethane	74–125	≤ 20	64–135	≤ 30
	1,1,2-Trichloroethane	75–127	≤ 20	65–135	≤ 30
	1,1-Dichloroethane	72–125	≤ 20	62–135	≤ 30
	1,1-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	1,1-Dichloropropene	75–125	≤ 20	65–135	≤ 30
	1,2,3-Trichlorobenzene	75–137	≤ 20	65–147	≤ 30
	1,2,3-Trichloropropane	75–125	≤ 20	65–135	≤ 30
	1,2,4-Trichlorobenzene	75–135	≤ 20	65–145	≤ 30
	1,2,4-Trimethyl Benzene	75-125	≤ 20	65–135	≤ 30
	1,2-Dichloroethane	68–127	≤ 20	58–137	≤ 30
	1,2-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1,2-Dibromo-3-chloropropane	59–125	≤ 20	49–135	≤ 30
	1,2-Dichloropropane	70–125	≤ 20	60–135	≤ 30
	1,2-Dibromoethane	75-125	≤ 20	65–135	≤ 30
	1,3,5-Trimethylbenzene	72–112	≤ 20	62–135	≤ 30
	1,3-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1,4-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1-Chlorohexane	75-125	≤ 20	65–135	≤ 30
	2,2-Dichloropropane	75-125	≤ 20	65–135	≤ 30
	2-Chlorotoluene	73–125	≤ 20	63–135	≤ 30
	4-Chlorotoluene	74–125	≤ 20	64–135	≤ 30
	Benzene	75–125	≤ 20	65–135	≤ 30
	Bromobenzene	75–125	≤ 20	65–135	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Volatile Organics (Cont) SW5030A/SW8260A (W, S)	Bromochloromethane	73–125	≤ 20	63–135	≤ 30
	Bromodichloromethane	75–125	≤ 20	65–135	≤ 30
	Bromoform	75–125	≤ 20	65–135	≤ 30
	Bromomethane	72–125	≤ 20	62–135	≤ 30
	Carbon Tetrachloride	62–125	≤ 20	52–135	≤ 30
	Chlorobenzene	75–125	≤ 20	65–135	≤ 30
	Chlorodibromomethane	75–125	≤ 20	65–135	≤ 30
	Chloroethane	65–125	≤ 20	55–135	≤ 30
	Chloroform	74–125	≤ 20	64–135	≤ 30
	Chloromethane	75-125	≤ 20	65–135	≤ 30
	Cis-1,2-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	Cis-1,3-Dichloropropene	74–125	≤ 20	64–135	≤ 30
	Dibromochloromethane	73–125	≤ 20	63–135	≤ 30
	Dibromomethane	69–127	≤ 20	59–137	≤ 30
	Dichlorodifluoromethane	75-125	≤ 20	65–135	≤ 30
	Dichloropropene	75–125	≤ 20	65–135	≤ 30
	Ethylbenzene	75–125	≤ 20	65–135	≤ 30
	Hexachlorobutadiene	75–125	≤ 20	65–135	≤ 30
	Isopropylbenzene	75–125	≤ 20	65–135	≤ 30
	m-Xylene	75–125	≤ 20	65–135	≤ 30
	Methylene Chloride	75–125	≤ 20	65–135	≤ 30
	n-Butylbenzene	75–125	≤ 20	65–135	≤ 30
	n-Propylbenzene	75–125	≤ 20	65–135	≤ 30
	Naphthalene	75–125	≤ 20	65–135	≤ 30
	o-Xylene	75–125	≤ 20	65–135	≤ 30
	p-Isopropyltoluene	75–125	≤ 20	65–135	≤ 30
	p-Xylene	75–125	≤ 20	65–135	≤ 30
	Sec-Butylbenzene	75–125	≤ 20	65–135	≤ 30
	Styrene	75–125	≤ 20	65–135	≤ 30
	Trichloroethene	71–125	≤ 20	61–135	≤ 30
	Tetrachloroethylene	71–125	≤ 20	61–135	≤ 30
	Toluene	74–125	≤ 20	64–135	≤ 30
	Trans-1,2-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	Trans-1,3-Dichloropropene	66–125	≤ 20	56–135	≤ 30
	Trichlorofluoromethane	67–125	≤ 20	57–135	≤ 30
	Vinyl Chloride	46–134	≤ 20	36–144	≤ 30
	Xylenes, Total	75–125	≤ 20	65–135	≤ 30
	Surrogates:				
	Dibromofluoromethane	75–125	NA	65–135	NA
	Toluene-D8	75–125	NA	65–135	NA
	4-Bromofluorobenzene	75–125	NA	65–135	NA
	1,2-Dichloroethane-D4	62–139	NA	52–149	NA

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Semivolatile Organics Base/Neutral Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S)	1,2,4-Trichlorobenzene	44–142	≤ 20	34–152	≤ 30
	1,2-Dichlorobenzene	42–155	≤ 20	32–135	≤ 30
	1,3-Dichlorobenzene	36–125	≤ 20	26–135	≤ 30
	1,4-Dichlorobenzene	30–125	≤ 20	25–135	≤ 30
	2,4-Dinitrotoluene	39–139	≤ 20	29–149	≤ 30
	2,6-Dinitrotoluene	51–125	≤ 20	41–135	≤ 30
	2-Chloronaphthalene	60–125	≤ 20	50–135	≤ 30
	2-Methylnaphthalene	41–125	≤ 20	31–135	≤ 30
	2-Nitroaniline	50–125	≤ 20	40–135	≤ 30
	3,3'-Dichlorobenzidine	29–175	≤ 20	25–175	≤ 30
	3-Methylphenol	41–144	≤ 20	31–154	≤ 30
	3-Nitroaniline	51–125	≤ 20	41–135	≤ 30
	4-Bromophenyl Phenyl Ether	53–127	≤ 20	43–137	≤ 30
	4-Chloroaniline	45-136	≤ 20	35-146	≤ 30
	4-Chlorophenyl Phenyl Ether	51–132	≤ 20	41–142	≤ 30
	4-Nitroaniline	40–143	≤ 20	30–153	≤ 30
	Acenaphthalene	47–125	≤ 20	37–135	≤ 30
	Acenaphthene	49–125	≤ 20	39–135	≤ 30
	Anthracene	45–165	≤ 20	35–175	≤ 30
	Benz (a) Anthracene	51–133	≤ 20	41–143	≤ 30
	Benzo (a) Pyrene	41–125	≤ 20	31–135	≤ 30
	Benzo (b) Fluoranthene	37–125	≤ 20	27–1 35	≤ 30
	Benzo (g,h,i) Perylene	34–149	≤ 20	25–159	≤ 30
	Benzo (k) Fluoranthene	37–125	≤ 20	27–135	≤ 30
	Benzyl Alcohol	35–125	≤ 20	25–135	≤ 30
	Bis (2-chloroethoxy) Methane	49–125	≤ 20	39–135	≤ 30
	Bis (2-chloroethyl) Ether	44–125	≤ 20	34–135	≤ 30
	Bis (2-chloroisopropyl) Ether	36–166	≤ 20	26–175	≤ 30
	Bis (2-ethylhexyl) Phthalate	33–129	≤ 20	25–139	≤ 30
	Butyl Benzyl Phthalate	26–125	≤ 20	25–135	≤ 30
	Carbazole	34–132	≤ 20	25–142	≤ 30
	Chrysene	55–133	≤ 20	45–143	≤ 30
	Di-n-Butyl Phthalate	34–126	≤ 20	25–136	≤ 30
	Di-n-Octyl Phthalate	38–127	≤ 20	28–137	≤ 30
	Dibenzo (a,h) Anthracene	50–125	≤ 20	40–135	≤ 30
	Dibenzofuran	52–125	≤ 20	42–135	≤ 30
	Diethyl Phthalate	37–125	≤ 20	27–135	≤ 30
	Dimethyl Phthalate	25–175	≤ 20	25–175	≤ 30
	Fluoranthene	47–125	≤ 20	37–135	≤ 30
	Fluorene	48–139	≤ 20	38–149	≤ 30
	Hexachlorobenzene	46–133	≤ 20	36–143	≤ 30
	Hexachlorobutadiene	25–125	≤ 20	25–135	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Semivolatile Organics Base/Neutral Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S) (Cont)	Hexachlorocyclopentadiene	41–125	≤ 20	31–135	≤ 30
	Hexachloroethane	25–153	≤ 20	25–163	≤ 30
	Indeno (1,2,3-c,d) Pyrene	27–160	≤ 20	25–170	≤ 30
	Isophorone	26–175	≤ 20	25–175	≤ 30
	N-Nitrosodi-n-propylamine	37–125	≤ 20	27–135	≤ 30
	N-Nitrosodiphenylamine	27–125	≤ 20	25–135	≤ 30
	Naphthalene	50–125	≤ 20	40–135	≤ 30
	Nitrobenzene	46–133	≤ 20	36–143	≤ 30
	p-Chloroaniline	56–125	≤ 20	46–135	≤ 30
	Phenanthrene	54–125	≤ 20	44–135	≤ 30
	Pyrene	47–136	≤ 20	37–146	≤ 30
Semivolatile Organics Acid Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S)	2,4,5-Trichlorophenol	25–175	≤ 20	25–175	≤ 30
	2,4,6-Trichlorophenol	39–128	≤ 20	29–138	≤ 30
	2,4-Dichlorophenol	46–125	≤ 20	36–135	≤ 30
	2,4-Dimethylphenol	45–139	≤ 20	35–149	≤ 30
	2,4-Dinitrophenol	30–151	≤ 20	25–161	≤ 30
	2-Chlorophenol	41–125	≤ 20	31–135	≤ 30
	2-Methylphenol	25–125	≤ 20	25–135	≤ 30
	2-Nitrophenol	44–125	≤ 20	34–135	≤ 30
	4,6-Dinitro-2-Methyl Phenol	26–134	≤ 20	25–144	≤ 30
	4-Chloro-3-Methyl Phenol	44–125	≤ 20	34–135	≤ 30
	4-Methylphenol	33–125	≤ 20	25–135	≤ 30
	4-Nitrophenol	25–131	≤ 20	25–141	≤ 30
	Benzoic Acid	25–162	≤ 20	25–172	≤ 30
	Pentachlorophenol	28–136	≤ 20	38–146	≤ 30
	Phenol	25–125	≤ 20	25–135	≤ 30
	Surrogates:				
	2,4,6-Tribromophenol	25–134	NA	25–144	NA
	2-Fluorobiphenyl	43–125	NA	34–135	NA
	2-Fluorophenol	25–125	NA	25–135	NA
	Nitrobenzene-D5	32–125	NA	25–135	NA
	Phenol-D5	25–125	NA	25–135	NA
	Terphenyl-D14	42–126	NA	32–136	NA
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW2550A/SW8310 (S)	1-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	2-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	Acenaphthalene	49–125	≤ 30	39–135	≤ 50
	Acenaphthene	43–130	≤ 30	33–140	≤ 50
	Anthracene	54–125	≤ 30	44–135	≤ 50
	Benzo (a) Anthracene	39–135	≤ 30	29–145	≤ 50
	Benzo (a) Pyrene	52–125	≤ 30	42–135	≤ 50
	Benzo (b) Fluoranthene	31–137	≤ 30	25–147	≤ 50
	Benzo (g,h,i) Perylene	53–125	≤ 30	43–135	≤ 50
	Benzo (k) Fluoranthene	60–129	≤ 30	50–139	≤ 50

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
	Chrysene	59–134	≤ 30	49–144	≤ 50
	Dibenzo (a,h) Anthracene	51–125	≤ 30	41–135	≤ 50
	Fluoranthene	42–125	≤ 30	32–135	≤ 50
	Fluorene	53–125	≤ 30	43–135	≤ 50
	Indeno (1,2,3-c,d) Pyrene	55–125	≤ 30	45–135	≤ 50
	Naphthalene	43–125	≤ 30	33–135	≤ 50
	Phenanthrene	52–129	≤ 30	42–139	≤ 50
	Pyrene	55–125	≤ 30	45–135	≤ 50
	Surrogates:				
	Terphenyl-D14	25–157	NA	22–167	NA
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S)	Aluminum	80–120	≤ 15	80–120	≤ 25
	Antimony	80–120	≤ 15	80–120	≤ 25
	Arsenic	80–120	≤ 15	80–120	≤ 25
	Barium	80–120	≤ 15	80–120	≤ 25
	Beryllium	80–120	≤ 15	80–120	≤ 25
	Cadmium	80–120	≤ 15	80–120	≤ 25
	Calcium	80–120	≤ 15	80–120	≤ 25
	Chromium	80–120	≤ 15	80–120	≤ 25
	Cobalt	80–120	≤ 15	80–120	≤ 25
	Copper	80–120	≤ 15	80–120	≤ 25
	Iron	80–120	≤ 15	80–120	≤ 25
	Lead	80–120	≤ 15	80–120	≤ 25
	Magnesium	80–120	≤ 15	80–120	≤ 25
	Manganese	80–120	≤ 15	80–120	≤ 25
	Molybdenum	80–120	≤ 15	80–120	≤ 25
	Nickel	80–120	≤ 15	80–120	≤ 25
	Potassium	80–120	≤ 15	80–120	≤ 25
	Selenium	80–120	≤ 15	80–120	≤ 25
	Silver	80–120	≤ 15	80–120	≤ 25
	Sodium	80–120	≤ 15	80–120	≤ 25
	Thallium	80–120	≤ 15	80–120	≤ 25
	Vanadium	80–120	≤ 15	80–120	≤ 25
	Zinc	80–120	≤ 15	80–120	≤ 25
SW3020A/SW7421 (W) SW3050A/SW7421 (S)	Lead	74-124	≤ 15	74-124	≤ 25
SW3020A/SW7131A (W) SW3050A/SW7131A (S)	Cadmium	80-122	≤ 15	80-122	≤ 15
Common Anions SW9060	Bromide	86–112	≤ 20	86–112	≤ 30
	Chloride	91–111	≤ 20	91–111	≤ 30
	Fluoride	86–114	≤ 20	86–114	≤ 30
	Nitrate	90–110	≤ 20	90–110	≤ 30
	Nitrite	88–116	≤ 20	88–116	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Common Anions	Phosphate	87–110	≤ 20	87–110	≤ 30
SW9060 (Cont)	Sulfate	88–115	≤ 20	88–115	≤ 30
E160.1	Total Dissolved Solids	NA	≤ 20	NA	NA
E160.2	Total Suspended Solids	NA	≤ 20	NA	NA
E310.1	Alkalinity	80-120	≤ 20	80-120	NA
E353.1	Nitrogen, nitrate/nitrite	80-120	≤ 20	80-120	NA
SW9050	Conductance	NA	≤ 20	NA	NA
SW9040	pH	NA	NA	NA	NA

SOURCE: AFCEE QAPP, Version 1.1, February 1996
[a] QC = Quality Control
[b] %R = Percent Recovery
[c] RPD = Relative percent difference
[d] W = Water
[e] S = Soil [f] NA=Not Applicable

TABLE 1.1 (cont)
QC ACCEPTANCE CRITERIA
SITE SAMPLING AND ANALYSIS PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatle Organics	Freon 12	70-130	±30
	Chloromethane	70-130	±30
	Freon 114	70-130	±30
	Vinyl Chloride	70-130	±30
	Bromomethane	70-130	±30
	Chloroethane	70-130	±30
	Freon 11	70-130	±30
	1,1-Dichloroethene	70-130	±30
	Dichloromethane (Methylene Chloride)	70-130	±30
	Trichlorotrifluoroethane (Freon 113)	70-130	±30
	1,1-Dichloroethane	70-130	±30
	cis-1,2-Dichloroethene	70-130	±30
	Chloroform	70-130	±30
	1,2-Dichloroethane	70-130	±30
	Methyl Chloroform (1,1,1-Trichloroethane)	70-130	±30
	Benzene	70-130	±30
	Carbon Tetrachloride	70-130	±30

TABLE 1.1 (Continued)
QC[a/] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatle Organics (Cont)	1,2-Dichloropropane	70-130	±30
	Trichloroethene	70-130	±30
	cis-1,3-Dichloropropene	70-130	±30
	trans-1,3-Dichloropropene	70-130	±30
	1,1,2-Trichloroethane	70-130	±30
	Toluene	70-130	±30
	1,2-Dibromethane (EDB)	70-130	±30
	Tetrachloroethene	70-130	±30
	Chlorobenzene	70-130	±30
	Ethylbenzene	70-130	±30
	m,p-Xylene	70-130	±30
	0-Xylene	70-130	±30
	Styrene	70-130	±30
	1,1,2,2-Tetrachloroethane	70-130	±30
	1,3,5-Trimethylbenzene	70-130	±30
	1,2,4-Trimethylbenzene	70-130	±30
	1,2-Dichlorobenzene	70-130	±30
	Chlorotoluene (Benzyl Chloride)	70-130	±30
	1,4-Dichlorobenzene	70-130	±30
	1,3-Dichlorobenzene	70-130	±30
	1,2,4-Trichlorobenzene	70-130	±30
	Hexachlorobutadiene	70-130	±30
	Propylene	60-140	±40
	1,3-Buradiene	60-140	±40
	Acetone	60-140	±40
	Carbon Disulfide	60-140	±40
	Isopropanol	60-140	±40
	trans-1,2-Dichloroethene	60-140	±40
	Vinyl Acetate	60-140	±40
	Chloroprene	60-140	±40
	2-Butanone (Methyl Ethyl Ketone)	60-140	±40
	Hexane	60-140	±40
	Tetrahydrofuran	60-140	±40
	Cyclohexane	60-140	±40
	1,4-Dioxane	60-140	±40
	Bromodichloromethane	60-140	±40
	4-Methyl-2-Pentanone (MIBK)	60-140	±40
	2-Hexanone	60-140	±40
	Dibromochloromethane	60-140	±40
	Bromoform	60-140	±40
	4-Ethyltoluene	60-140	±40
	Ethanol	60-140	±40
	Methyl-Butyl Ether (MTBE)	60-140	±40
	Heptane	60-140	±40

TABLE 1.1 (Continued)
QC[a/] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatle Organics (Cont)	<u>Surrogates</u>		
	Octafluorotoluene	70-130	±30
	Toluene-d8	70-130	±30
	4-Bromofluorobenzene	70-130	±30
	<u>Internal Standards (I.S.)</u>		
	Bromochloromethane		
	1,4-Difluorobenzene		
	Chlorobenzene-d5		
ASTM Method D3416 for Methane in Soil Gas	Methane	75-125	±25

Criteria: Sample, QC sample and blank I.S. area must be within ±40% of the calibration checks I.S. area. Retention Time (R.T.) must be within ±0.5 minutes of the calibration check's R.T.

Table 1.1 QC Acceptance Criteria

Table 1.1 (C)

Table 1.1 (C)

Table 1.1 (C)

Table 1.1 (C)

Table 1.1 (C)

Table 1.1 (C)

Table 1.1 (C)

1.4.2 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value. Accuracy is expressed as a bias (high or low) and is determined by calculating percent recovery (%R) from MS/MSDs, LCSs, and surrogate spikes. MS/MSD and surrogate spike %Rs indicate accuracy relevant to a unique sample matrix. LCS %Rs indicate accuracy relevant to an analytical batch lot, and are strictly a measure of analytical accuracy conditions independent of samples and matrices. The %R of an analyte, and the resulting degree of accuracy expected for the analysis of QC spiked samples, are dependent upon the sample matrix, method of analysis, and the compound or element being measured. The concentration of the analyte relative to the detection limit of the method also is a major factor in determining the accuracy of the measurement.

Accuracy is expressed as %R and is calculated as follows:

$$\%R = [(A-B)/C] \times 100$$

where:

A = spiked sample concentration

B = measured sample concentration (without spike)

C = concentration of spike added.

Accuracy criteria for the laboratory are defined by control limits listed in Table 1.1.

1.4.3 Completeness

Completeness is defined as the percentage of laboratory measurements judged to be valid on a method-by-method basis. Valid data are defined as all data and/or qualified data considered to meet the DQOs for this project. Data completeness is expressed as percent complete (PC) and should be ≥ 90 percent. The goal for meeting analytical holding times is 100 percent. At the end of each sampling event, the completeness of the data will be assessed. If any data omissions are apparent, the parameter in question will be resampled and/or reanalyzed, if feasible. The laboratory results will be monitored as they become available to assess laboratory performance and its effect on data completeness requirements. When appropriate, additional samples will be collected to ensure that laboratory performance meets PC requirements.

PC is calculated as follows:

$$PC = \frac{N_A}{N_I} X100$$

Where:

N_A = Actual number of valid analytical results obtained

N_I = Theoretical number of results obtainable under ideal conditions.

1.4.4 Comparability

Comparability expresses the confidence with which data from one sample, sampling round, site, laboratory, or project can be compared to those from another. Comparability during sampling is dependent upon sampling program design and time periods. Comparability during analysis is dependent upon analytical methods, detection limits, laboratories, units of measure, and sample preparation procedures.

Comparability is determined on a qualitative rather than quantitative basis. For this project, comparability of all data collected will be ensured by adherence to standard sample collection procedures, standard field measurement procedures, and standard reporting methods, including consistent units. For example, concentrations will be reported in a manner consistent with general industry practice (e.g., soil data will be reported on a dry-weight basis).

In addition, to support the comparability of fixed-base laboratory analytical results with those obtained in previous or future testing, all samples will be analyzed by USEPA-approved methods, where available. The USEPA-recommended maximum permissible holding times for organic and inorganic parameters will not be exceeded. All analytical standards will be traceable to standard reference materials. Instrument calibrations will be performed in accordance with USEPA method specifications, and will be checked at the frequency specified for the methods. The results of these analyses can then be compared with analyses by other laboratories and/or with analyses for other sites addressed by this site investigation.

1.4.5 Representativeness

Representativeness expresses the extent to which collected data define site contamination. Where appropriate, sample results will be statistically characterized to determine the degree to which the data accurately and precisely represent a characteristic of a population, parameter variation at a sampling point, a process, or an environmental condition.

Sample collection, handling, and analytical procedures will strive to obtain the most representative sample possible. Representative samples will be achieved by the following:

- Collection of samples from locations fully representing site conditions;
- Use of appropriate sampling procedures, including equipment and equipment decontamination;
- Use of appropriate analytical methods for the required parameters and project reporting limits; and
- Analysis of samples within the required holding times.

Sample representativeness also is affected by the portion of each collected sample that is chosen for analysis. The laboratory will adequately homogenize all samples prior to taking aliquots for analysis to ensure that the reported results are representative of the sample received. Because many homogenization techniques may cause loss of contaminants through volatilization, homogenization for all volatile organic compound (VOC) method analyses will be performed with extreme care to minimize these risks.

SECTION 2

SOIL GAS SAMPLING

2.1 INTRODUCTION

Soil gas will be used as an indicator of subsurface hydrocarbon contamination and to assess the need for landfill gas controls at the site. The use of shallow soil gas probes to delineate potential subsurface contamination and to assess landfill gas levels has several economic and technical advantages over more traditional drilling and soil sampling techniques. The labor and equipment cost can be significantly less than a conventional drilling and sampling team. Many new hydraulically driven, multi-purpose probes can be used for soil gas sampling. These probes can be advanced as quickly as conventional augers and do not produce drill cuttings which can require expensive analysis and disposal. Further, soil gas sampling can represent the average chemistry of several cubic feet of soil as compared to a discrete soil sample, which can only describe a few cubic inches of the subsurface. This is of particular importance in risk-based remediation projects where the extent of contamination and the degree of contaminant removal can most accurately be determined by using multiple soil gas sampling locations.

2.2 SOIL GAS SAMPLING FREQUENCY AND LOCATIONS

Soil gas screening will be completed at approximately 50 locations on a 100 foot by 100 foot grid across the Landfill B site (see Section 4.2). The primary purpose of this initial screening will be to locate and "hot spots" which exhibit high levels of volatile organics. A handheld Gas Tech multi-gas meter will be used to provide a semi-quantitative screening to determine total volatile hydrocarbon in the soil gas. If significant TVH levels are detected, the "hot spots" will be resampled using a Summa™ Canister and analyzed in a certified laboratory using EPA Method TO-14. A secondary purpose for soil gas sampling will be to obtain additional information on the concentraion of methane in the shallow soil gas. Each of the 50 locations will be sampled with a portable explosimeter (the Gas Tech multi-gas meter) to determine the relative concentration of methane, oxygen and carbon dioxide at each location. Samples that are selected for TO-14 analysis will also be analzed for methane using laboratory method ASTM D3416. These results will be used to provide some correlation between field screening estimates of methane levels to laboratory results.

It is anticipated that the remedial implementation plan for Landfill B will specify a long-term soil gas sampling plan that complies with 310 CMR 19.118. Details of this sampling will be included in the remedial implementation plan.

2.3 SOIL GAS SAMPLING PROCEDURES

The test equipment and methods that will be required to conduct field soil gas sampling at this site are generally described in *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (Downey and Hall, 1994). In addition to these general procedures, special procedures outlined in *MADEP's Landfill Technical Guidance Manual* (MADEP, 1993) will be used to sample the landfill gas at this site. During soil gas screening, soil gas will be collected using a stainless-steel soil gas probe (5/8 or 3/4 inch O.D.). Probes will be pushed by a Geoprobe™ or hand-driven to a depth of approximately 4 feet at each location. The probe will be retracted approximately 6 inches to expose the soil gas screen to the soil.

A 1-cfm vacuum pump will be operated for 30 seconds at each location to purge soil gas and collect a representative sample. A Gas Tech multi-gas meter will be continuously sample the purge stream to insure that total volatile hydrocarbon (TVH) levels have stabilized. Once stablized, oxygen, methane, TVH and carbon dioxide levels will be recorded. At several points with high TVH levels a sample will be collected in a 3-liter Tedlar bag for laboratory analysis. The multi-gas meter has range settings of 0 to 25 percent for both O_2 and CO_2. Before analyzing samples, the analyzer must be calibrated and the battery charge checked. The analyzer will be calibrated daily using atmospheric conditions of O_2 (20.9 percent) and CO_2 (0.05 percent) and a gas standard containing 0.0 percent O_2 and 5.0 percent CO_2.

Total volatile hydrocarbon and methane concentrations also will be measured at the Landfill B site. The TVH analyzer used at the site will be capable of measuring hydrocarbon and methane concentrations in the range of 1 to 20,000 parts per million, volume per volume (ppmv). For areas with high methane concentrations, an additional sample dilution may be needed to bring the sample within the instrument range. The analyzer is also equiped with a charcoal prefilter which will allow the operator to distinguish between methane and non-methane hydrocarbons. The TVH analyzer will be calibrated daily using a 5,000 ppmv methane calibration gas.

Sample locations identified for laboratory analytical, compound-specific analysis will be resampled using 3-liter Tedlar® bags and a vacuum chamber. The samples will then be transferred to 1-liter SUMMA® canisters and shipped to Air Toxics, Inc. in Folsom, California for compound-specific analysis using US Environmental Protection Agency (USEPA) analytical Method TO-14. This method includes all of the 12 targeted landfill gas compounds specified by MADEP Landfill Technical Guidance Manual (MADEP,1993). The laboratory will also analyze for methane using ASTM Method D3416.

Field quality assurance/quality control (QA/QC) procedures for soil gas will include collection of one field duplicate for every 10 samples collected (e.g., frequency of 10 percent), use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical method to be used.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

The analytical laboratory will conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas since only one analytical method will be used).

SECTION 3

SOIL/SEDIMENT SAMPLING

3.1 INTRODUCTION

Soil and sediment sampling will be performed as part of the site characterization. Several soil samples will be collected in saturated soils which exhibit elevated volatile organics in groundwater screening samples. Sediment samples will be collected from the bottom of the drainage swale south of the landfill where past sampling has indicated contaminants of potential concern exist. The following sections describe the soil and sediment sampling locations, borehole installation, soil sampling, procedures for equipment decontamination, and datum surveying procedures to be used as part of the soil sampling field effort.

3.2 SAMPLING LOCATIONS

Subsurface soil sampling will take place at locations where groundwater screening indicates higher concentrations of VOCs may exist. The exact number of samples will be determined in the field but is not expected to exceed seven samples. Soils samples will be collected from a depth of approximately 2-4 feet below the water table. Sediment sampling locations have been identified in Section 4 of the Work Plan. These locations were primarily selected based on past detections of contaminants of potential concern. Sediment samples will be collected from the upper 6-inches of the sediment at each location.

3.3 SOIL AND SEDIMENT SAMPLING PROCEDURES

3.3.1 Soil Sampling

Soil sampling in unconsolidated soils will be accomplished using a Geoprobe® hydraulic sampling rig. The Geoprobe® will be used to advance a 2-inch-diameter sampler containing a butylene liner to the desired sampling depth. Once the desired sampling depth is attained, the end point of the sampler will be retracted and the sampler will be advanced approximately 4 feet until filled with soil. The sampler will be returned to the surface, the liner removed, and its ends capped with Teflon® squares and plastic caps. All sampling equipment will be decontaminated prior to use and between uses, as described in Section 3.8. If subsurface conditions are such that the planned installation technique does not produce acceptable results another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the Licensed Site Professional and will be appropriate for the subsurface lithologies present at the site.

The Parsons ES field hydrogeologist will be responsible for observing all borehole installation and sampling activities, maintaining a detailed log of the target sample interval, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.1. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination (e.g., staining, odor or elevated headspace screening readings);
- Soil or rock description of the target sampling interval, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- The depth of lithologic contacts and/or significant textural changes, measured and recorded to the nearest 0.1 foot (1 inch) if present within the target interval.

3.3.2 Sediment Sampling

Sediment samples will be collected from several locations where landfill runoff or leachate may have impacted a stormwater drain or wetland area. If possible sediment samples will be collected immediately following a precipitation event. Samples will be collected from the upper six inches of the sediment layer using a metal hand trowel, placed in a 500 ml glass jar with minimum headspace, and sealed using a teflon sheet and screw on lid.

3.4 SAMPLE HANDLING

This section describes the handling of soil and sediment samples from the time of sampling until the samples arrive at the laboratory.

3.4.1 Sample Containers and Labels

New, factory cleaned butylene sample sleeves and end caps (or glass jars for sediments) will be provided by Parsons ES or the laboratory. The sample label will be firmly attached to the sample sleeve immediately after sample collection, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample depth;
- Sampling date;

Sheet of

GEOLOGIC BORING LOG

BORING NO.		CONTRACTOR:		DATE SPUD:	
CLIENT:		RIG TYPE:		DATE CMPL:	
JOB NO.:		DRLG METHOD:		ELEVATION:	
LOCATION:		BORING DIA.:		TEMP.:	
GEOLOGIST:		DRLG FLUID		WEATHER:	
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1								
	5								
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

Figure 3-1

- Sampling time; and
- Sample collector's initials.

3.4.2 Sample Preservation

Samples will be properly prepared for transportation to the laboratory by placing the samples in an adequately padded cooler containing ice to maintain an approximate shipping temperature of 4 degrees centigrade (°C).

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to Inchcape Testing Services in New Bedford, MA. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and in accordance with analytical method-specific holding times.

3.4.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling team and the other two copies will be sent to the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;

- Place and address of collection;
- Sample matrix;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the Parsons ES field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Sampler's identification;
- Any other relevant information.

3.5 LABORATORY ANALYSES

Laboratory analyses will be performed by Inchcape Testing Services on all soil samples and the required QA/QC samples (see Section 3.6 and Section 5). Soil samples will by analyzed by USEPA analytical method 8260 for volatile organic compounds and by USEPA analytical method 8270B for phenolic compounds. In addition to these two methods, sediment samples will also be analyzed for pesticides using method SW8081 and

cadmium using method SW7131A. All containers, preservatives, and shipping requirements will be consistent with the laboratory protocol. Laboratory personnel will specify any additional QC samples required. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site.

3.6 QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on the quality of field sampling activities (sampling, containerization, shipment, and handling) QA/QC trip blanks, field blanks, equipment rinseate samples, and field replicates will be sent to the laboratory. QA/QC sampling will include one replicate for soil samples (i.e., frequency of 10 percent), one rinseate sample (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual shipping cooler sent to the analytical laboratory containing samples for volatile organic compound (VOC) analysis. The procedures for the collection of field QA/QC samples are discussed in Section 5 of this SAP. Laboratory QA/QC procedures will include one matrix spike analysis, one laboratory control sample, and one laboratory blank sample test for each specific analysis requested.

3.7 MINIMIZATION AND MANAGEMENT OF SOIL RESIDUALS

Borehole installation and soil sampling activities using the Geoprobe® will generate no soil cuttings that will require proper handling and, if contaminated, proper disposal.

3.8 EQUIPMENT DECONTAMINATION PROCEDURES

Water to be used in equipment cleaning will be obtained from one of the Base's onsite water supplies. Westover ARB personnel will assist Parsons ES field personnel in locating a suitable source. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for decontamination. A decontamination water blank will be collected from the potable water source. The procedures for the collection of the decontamination water blank are described in Section 5. The Parsons ES field hydrogeologist will make the final determination as to the suitability of site water for these activities.

Prior to arriving at the site, and between each borehole installation, the Geoprobe® rods, samplers, tools and other downhole equipment will be decontaminated using a hot-water wash. During borehole installation operations, the rig, samplers, and any other downhole equipment will be decontaminated at a temporary decontamination pad that will be set up adjacent to each borehole location. The decontamination fluids will be stored in 55-gallon Department of Transportation (DOT) approved drums for proper treatment and disposal.

All sampling tools will be cleaned with a clean water/phosphate-free detergent mix, a clean water rinse, isopropyl alcohol rinse, and a final distilled water rinse. Materials that cannot be cleaned to the satisfaction of the Parsons ES field hydrogeologist will not be used. All decontamination activities will be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. The Geoprobe® rig will not be allowed onsite unless it is free from leaks in all hydraulic and fuel lines, and is free of any exterior oil and grease.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled decontamination fluids will not be allowed to enter any boring. Berms around the borehole and surficial bentonite packs, as appropriate, will be used to prevent cross-contamination.

3.9 SURVEY OF BOREHOLE LOCATIONS

The horizontal location of the new boreholes will be located by Parsons ES field personnel after completion of sampling procedures. Horizontal locations will be measured relative to previously installed groundwater wells that have established coordinates (i.e., previously surveyed by a register surveyor). Horizontal distances will be recorded to the nearest 0.1 foot by measuring the distance from each borehole to three established locations (monitoring wells or other previously surveyed locations deemed more appropriate by field personnel). These distances will be used to locate each borehole on any additional maps generated as part of the risk-based investigation.

3.10 BOREHOLE ABANDONMENT

Geoprobe® sampling operations will produce boreholes that are approximately 2.5 inches in diameter. These holes will be abandoned by filling with pelletized bentonite. The bentonite will be hydrated in place with potable water at 2-foot intervals to ensure proper hydration and subsequent sealing of the borehole. The concrete at the site will be patched with ready-mix concrete troweled to match the existing grade.

SECTION 4

GROUNDWATER AND SURFACE WATER SAMPLING

4.1 INTRODUCTION

This section describes the scope of work required for collecting groundwater and surface water samples from existing and new monitoring wells and several permanent surface water sampling stations. Two levels of sampling will be performed at this site. Initial groundwater screening will be completed at 50 temporary sampling points using a direct push groundwater sampling probe and a peristaltic pump to purge and collect samples. Sampling of permenently installed new and existing wells will be completed using a combination of handbailing for VOC samples and a peristaltic pump for collection of all non-volatile and geochemical parameteres. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Groundwater/ surface water sampling will be conducted by qualified Parsons ES scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed the work plan and this site-specific sampling and analysis plan prior to sample acquisition and will have a copy of both available onsite for reference.

Activities that will occur during groundwater/ surface water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of existing wells, including:
  - Protective cover, cap and lock,
  - External surface seal and pad,
  - Well stick-up, cap, and datum reference,
  - Internal surface seal,
  - Condition of any dedicated equipment, if present;
- Groundwater sampling, including:
  - Water level measurements,

- Visual inspection of borehole water,
- Well purging,
- Sampling;

• Surface water sampling, including:
  - Inspection of permanent location marker (i.e., visibility, integrity),
  - Visual inspection of surface water,
  - Sampling;

• Sample preservation and shipment, including:
  - Sample preparation and preservation, as appropriate,
  - Onsite measurement of physical parameters,
  - Sample labeling,
  - Sample packaging in appropriate shipping containers;

• Completion of sampling records;

• Completion of chain-of-custody records; and

• Sample shipment via overnight courier.

Detailed groundwater/ surface water sampling and sample handling procedures are presented in following sections.

4.2 GROUNDWATER/ SURFACE WATER SAMPLING LOCATIONS

4.2.1 Groundwater Screening

To better define the possible sources of dissolved VOC contamination eminating from Landfill B, a screening of shallow groundwater samples at approximately 50 locations will be completed. The same 100 foot by 100 foot sampling grid used for soil gas sampling will also be used for shallow groundwater screening. Samples will be collected using a temporary stainless steel probe advanced to approximately four feet below the groundwater surface at each location. Sampling will proceed from the outer, less contaminated areas to the inner, more contaminated areas to minimize the potential for cross-contamination.

4.2.2 Permanent Well Sampling

Groundwater samples will be collected from 23 of the existing wells on the site and several sets of new nested monitoring points which will be constructed using the Geoprobe™. The location of these wells is shown in Figure 4.1 of the Work Plan.

4.2.3 Surface Water Sampling

Surface water sampling will take place at approximately 3 locations surrounding the landfill. For drainage systems passing by or through the landfill, both upgradient and downgradient samples will be collected to determine the potential impact of landfill surface runoff or leachate to surface water. Surface water sampling stations will be permanently marked with a metal stake to maintain consistency in future monitoring events. If possible, sampling will be completed during a low-flow period to minimize the impact of dilution on surface water contamainant concentrations.

4.3 MONITORING POINT CONSTRUCTION AND PREPARATION FOR SAMPLING

4.3.1 Temporary Screening Probes

The Geoprobe™ unit will be used to advance a 1-inch O.D. stainless-steel probe which has a 2-foot section of 0.01-inch slotted steel for collecting groundwater samples. The probe will be advanced to at least 4 feet below the groundwater table. A section of dedicated high-density polyethylene (HDPE) tubing will be lowered inside the probe and connected to a pressure guage to determine the approximate depth that groundwater is first encountered. The approximate groundwater depth below ground surface will be recorded to the nearest 0.1 foot. The tubing will then be inserted to within 1 foot of the bottom of the probe and connected to a peristaltic pump for purging. Each temporary well-point will be purged until dissolved oxygen and temperature readings have stabilized. Once stable readings are obtained, a sample will collected from the peristaltic pump discharge for VOC analysis using a field GC. Water from the peristaltic pump can be directly discharged into the sample container. The water should be carefully poured down the inner walls of a 40-ml sample bottle to minimize aeration of the sample. Sample containers for VOC analysis will be filled at approximately 200 ml/min and should fill the entire container to eliminated any headspace. Two sample containers will be collected at each location, one for immediate GC analysis and a second for potential shipment to a fixed laboratory. Both sample containers will contain a pH<2 HCL preservative. These samples will be labelled and taken to the field GC operator for analysis procedures described in Section 4.7.

4.3.2 Permanent Monitoring Point Installation

Permanent groundwater monitoring points will be installed at 17 locations. The groundwater monitoring points will be constructed through 2-inch-outside-diameter Geoprobe® drive rods using of 0.75-inch OD/0.5-inch ID PVC casing and well screen, flush-threaded, Schedule 40 polyvinyl chloride (PVC) well casing and screen. The screens will consist of 5-foot-long sections of 0.010-inch factory-slotted screen with treaded

bottom caps. The borehole will be backfilled with No. 10-20 Silica Sand pack to 1-foot above the top of the screen. Bentonite pellets will placed from the top of the sand pack to 6 inches below ground surface. The top of the casing will be sealed with a 1/2 PVC slip cap. At most locations, two monitoring points will be completed to collect groundwater samples from just below the grounwater surface and from a depth of approximately 40 feet bgs. The surface completion will consist of an 8-inch-diameter, flush-mounted well box set in a concrete collar sloping away from the well box and matching the site grade. The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

4.3.3 Preparation for Sampling New Monitoring Points and Existing Wells

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to the beginning of the sampling event. In addition, all record keeping materials will be gathered prior to leaving the office. A brief organizational meeting will be held to ensure proper communication between project management staff and field personnel.

4.4 EQUIPMENT DECONTAMINATION

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment may include water-level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the chemical constituents present at the Landfill B site, the following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (Liquinox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

All decontamination fluids will be temporarily placed in 55-gallon DOT approved containers for proper disposal.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling form. If pre-cleaned dedicated sampling equipment is used, the decontamination protocol specified above will not be required.

Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field. Equipment field blanks and equipment rinseate samples will be collected to assure that all containers and field equipment are free of contamination.

4.5 EQUIPMENT CALIBRATION

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as pH, electrical conductivity, and temperature. Additional details on the calibration of field equipment are presented in Section 6 of this SAP. Procedures for calibrating the field gas chromatograph are included in Addendum 1 to the SAP.

4.6 SAMPLING PROCEDURES

Special care will be taken to prevent contamination of the groundwater/ surface water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between wells. To prevent such contamination, the peristaltic pump and water level probe and cable used to determine static water levels and total well depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 4.4. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different well or station is sampled. New, clean tubing will be used for the peristaltic pump for each of the temporary "screening" wells sampled. Properly decontaminated or disposable bailers will be used to sample for VOCs in existing or new permanent wells. Wells will be sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated. Plastic will be placed around each of the wells to be sampled and sampling equipment will not be allowed to come in contact with the ground surface at any time during the sampling event.

The following paragraphs present the procedures for groundwater/ surface water sample acquisition from all groundwater/ surface water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the Parsons ES field scientist's field notebook.

4.6.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well or sampling location will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well. New, clean plastic (4 to 6 mil) we be placed around the well to prevent the contamination of both the ground surface and any equipment that may come into contact with the ground surface.

4.6.2 Water Level and Total Depth Measurements

Prior to removing any water from new monitoring points or existing wells, the static water level will be measured. An electrical water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. If the total depth of the well is not known or is suspected to be inaccurate, total well depth will be measured by slowly lowering the water level probe to the bottom of the well. Total well depth will be measured to the nearest 0.01 foot. Total depth will only be measured when absolutely necessary to minimize the amount of sediment disturbance in the well. Based on water level and total depth information, the volume of water to be purged from the well can be calculated.

4.6.3 Well Purging

The static groundwater inside each well will be purged using a peristaltic pump. The well will be purged at a very low flow rate [10 milliliters per minute (ml/min) to 1,000 ml/min]. The objective of micropurging is to remove a small volume of water at a low flow rate from a discrete portion of the screened interval of the well without disturbing stagnant water within the casing. Therefore, the well purge rate must never be greater than the recharge rate of the well. During purging, the water level in the well will be monitored to ensure that no drawdown in the well occurs. The water level monitoring will allow the sampling technician to control pumping rates to minimize drawdown. As long as no drawdown is observed during pumping, it may be assumed that the low pumping rate within the discrete, screened portion of the well has not pulled stagnant casing water into the sample.

The pH, temperature, dissolved oxygen, and specific conductivity will be continuously monitored during well purging using a flow-through cell. The flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using Teflon®-lined polyethylene tubing. New tubing will be used at each well. Purging will continue until the parameters have stabilized (less than 0.2 standard pH units or a 10-percent change for the other parameters over a 5-minute period) and the water is clear and free of fines. Research conducted on low-flow micropurging has found that dissolved oxygen and specific conductance readings are the most useful field indicator parameters for stabilization of background water chemistry during purging (Barcelona, *et. al.*, 1994). The research also concluded that stabilization of dissolved oxygen and specific conductance shows some correlation to stabilization of VOC concentrations in "formation" waters.

All purge water will be placed in DOT approved 55-gallon containers and disposed of properly. Parsons ES will be responsible for sampling, laboratory analysis, and arranging for the disposal of any contaminated or potentially contaminated purge and development water. It is anticipated that purge water will be clean enough to be disposed of at the site in accordance with the MCP. Drums will be staged and temporarily stored onsite until analytical results are received to confirm on-site disposal.

4.6.4 Sample Extraction

A peristaltic pump with new tubing for each well will be used to extract groundwater samples for all analysis except VOCs. Bailers will be used for collecting samples for VOCs analysis to minimize any potential volatilization due to the peristaltic pump vacuum. Both types of extraction equipment will be gently lowered into the water to prevent splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water sample will be transferred from the bottom of the bailer using a bottom emptying device to allow a controlled flow into the sample container. Water from the peristaltic pump can be directly discharged into the sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample containers for VOC analysis will be filled at approximately 200 ml/min and all other sample collection rates will not exceed 400 ml/min. Samples for VOC analysis will be collected after the well has been purged using the peristalic pump and after all field sampling parameters have been recorded at the well.

Four surface water samples will be collected at three permanent surface water monitoring stations that will be established along the drainage swale upstream and downstream of the landfill leachate area and the wetland area north of the railroad track (see Figure 4.1). The samples will be collected along the approximate centerline of the drainage swales to assess the impact of landfill surface runoff and leachate on the surface water quality. Surface water samples will be collected directly into the sample bottle by submerging the sample bottle beneath the surface of the water in the ditch or pond and allowing the water to slowly fill the bottle without exposure to the atmosphere. The sample bottle will be capped while submerged to prevent capture of air bubbles in the sample vial.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon containers used for well purge waters and disposed of in accordance with the MCP.

4.7 ONSITE CHEMICAL PARAMETER MEASUREMENT

Because many chemical parameters of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field using Hach® or CHEMetrics® test kits. In addition, a field GC will be used to provide a semi-quantitative analysis of VOCs from the 50 shallow groundwater screening points. The following discussion describes the field procedures for obtaining the onsite chemical parameter measurements. For information on individual instrument calibration procedures, please refer to the manufacture's calibration procedure for the instrument.

Groundwater quality measurements such as temperature, pH, specific conductivity, dissolved oxygen, and reduction/oxidation (redox) potential will be continuously monitored during well purging using a flow-through cell. The flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using Teflon®-lined polyethylene tubing. A new piece of tubing will be used for each well. All groundwater quality measuring equipment will be decontaminated following the procedures described in

Section 4.4. The groundwater quality measuring equipment will be calibrated between each well following the manufacturer's recommended calibration procedures. The measurements observed immediately before groundwater sampling begins will be considered the final measurements for the sample, and will be recorded in the field notebook and on the point-specific sampling form.

Groundwater quality measurements such as nitrate, nitrite, manganese, ferrous iron, sulfate, sulfide, and alkalinity will be measured in the field using HACH® or CHEMetrics® field analysis methods. All appropriate equipment and glassware associated with the field analysis of groundwater samples will be decontaminated following the procedures described in Section 4.4. Groundwater samples for these measurements will be collected after all sample containers for laboratory analyses have been collected. Two 250-ml bottles of groundwater will be collected and capped for field analysis. The field analysis of groundwater samples should begin immediately after collection. Direct sunlight, contact with air, and high temperatures may greatly affect the concentrations of the analytes in question. If possible, analyses will be run indoors, and groundwater samples will be capped and stored in a cooler with a temperature maintained at 4°C when not in use. Duplicate analyses will be run at a frequency of 25 percent, or one duplicate sample for every four field analyses. One blank (distilled water) analysis will be performed for each sampling round.

Samples for field GC analysis will be collected in two, 40-ml VOA vials, labelled and placed in an ice chest for transfer to the field GC operator. The field GC analytical procedure, including calibration has been included as Addendum 1 to this SAP. For this field screening effort, a duplicate analysis will be completed for 10 percent of the sample locations. Since the purpose of the field screening is to generally identify those areas of the landfill with higher dissolved VOC concentrations, acceptable detection limits for individual compounds such as 1,1,1 TCA will likely be in the 5-10 ppb range. Samples which exhibit higher VOC concentrations will be selected for laboratory analysis using EPA Methods SW8240 and SW8270. Since a field duplicate sample will be collected at each of the 50 locations, the second sample will be sent to the laboratory for analysis.

4.8 LABORATORY SAMPLE HANDLING

This section describes the handling of samples to be analyzed by the fixed-based laboratory from the time of sampling until the samples arrive at the laboratory.

4.8.1 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory. The sample containers will be filled as described in Section 4.6.4, and the container lids will be tightly closed. Container lids will not be removed at any time prior to sample collection. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;

SAMPLING LOCATION ____________
SAMPLING DATE(S)____________

GROUND WATER SAMPLING RECORD - MONITORING WELL ____________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ____________, 19___ ________ a.m./p.m.
SAMPLE COLLECTED BY: ________________ of ________________
WEATHER:____________________________________
DATUM FOR WATER DEPTH MEASUREMENT (Describe):____________________
____
____

MONITORING WELL CONDITION:

[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS:____________________
INNER PVC CASING CONDITION IS:____________________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe):____________
____
____

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH____________________
Items Cleaned (List):____________________
____
____

2 [ ] WATER DEPTH ____________________ FT. BELOW DATUM
Measured with:____________________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance:____________________
Odor:____________________
Other Comments:____________________

4 [ ] WELL EVACUATION:
Method:____________________
Volume Removed:____________________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors:____________________
Other comments:____________________

Figure 4.1

- Sample type (groundwater, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

4.8.2 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4°C.

4.8.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to Inchcape Testing Services of New Bedford MA. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and within method-specific holding times.

4.8.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed as described in Section 3.4.4.

4.8.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the Parsons ES field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
    - Sample appearance,
    - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Approx Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Figure 4.1

Groundwater/ surface water sampling activities will be recorded on a groundwater sampling form or in the field scientist's field notebook. Figure 4.1 shows an example of the groundwater sampling record.

4.9 LABORATORY ANALYSES

Laboratory analyses will be performed on all groundwater/ surface water samples and the required QA/QC samples (see Section 4.10). The analytical methods and detection limit requirements for this sampling event are listed in the Work Plan. Prior to sampling, arrangements will be made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with laboratory protocol.

Laboratory personnel will specify any additional QC samples and prepare bottles for all samples. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers with adequate padding and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

4.10 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES AND SAMPLING

Field QA/QC samples for groundwater/ surface water sampling will include collection of field duplicates; equipment rinseate samples, and field, and trip blanks; decontamination of the water level probe; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater/ surface water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain an approximate temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Groundwater/ surface water QA/QC sampling frequency will be 10 percent or one sample for every ten wells/locations sampled. In the event that less than ten wells will be sampled in an event, a minimum of one sample will be collected. This ten percent frequency also applies to equipment rinseate samples and field duplicates. One decontamination water sample and one field blank will be collected per sampling event. One trip blank will be sent with each sample shipment. The procedures for the collection of field QA/QC samples are described in Section 5. The laboratory should plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

SECTION 5

FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples will be collected during each sampling event. Definitions for field QA/QC samples are presented below.

5.1 FIELD DUPLICATES

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil and sediment samples are divided into two equal parts (replicates) for analysis. Field duplicates will be indistinguishable from other samples by the laboratory. Each of the field duplicates will be uniquely identified with a coded identifier, which will be in the same format as other sample identifiers. Duplicate sample results are used to assess the precision of the sample collection process. During the collection of VOC samples, compositing should not be performed due to the potential for target compound loss. Ten percent of all field samples will be field duplicates.

5.2 TRIP BLANKS

The trip blank is used to indicate potential contamination by VOCs or SVOCs during sample shipping and handling. A trip blank consists of analyte-free laboratory reagent water in a 40-milliliter (ml) glass vial sealed with a Teflon® septum. The blank accompanies the empty sample bottles to the field and is placed in each cooler containing water or soil matrix VOC/SVOC samples returning to the laboratory for analysis. The trip blank is not opened until analysis in the laboratory with the corresponding site samples.

5.3 EQUIPMENT RINSEATE BLANKS

Equipment rinseate blanks consist of reagent grade water poured into or pumped through the sampling device following decontamination. The rinseate is transferred to an appropriate sample bottle for the analysis and transported to the laboratory. The equipment rinseate samples are analyzed for the same laboratory parameters as the site samples. Equipment blanks are used to measure to contamination introduced to a sample set from improperly decontaminated sampling equipment.

5.4 DECONTAMINATION WATER BLANK

A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. One decontamination water blank will be collected for each water source used during the field work. Decontamination

water blanks are collected by filling the appropriate sample container directly from the potable water source. Decontamination water blanks are labeled, preserved, handled, and shipped in the same manner as an environmental water sample. The blank will be analyzed for the same analytes and parameters as the environmental samples.

5.5 FIELD BLANKS

A field blank is designed to assess the effects of ambient field conditions on sample results. A field blank will consist of a sample of reagent grade water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for the same analytes and parameters as the environmental samples.

SECTION 6

FIELD DATA REDUCTION, VALIDATION, AND REPORTING

The following sections describe field analytical instrumentation calibration, and field data reporting, validation, reduction, and review.

6.1 CALIBRATION PROCEDURES AND FREQUENCY FOR FIELD TEST EQUIPMENT

Instruments and equipment used to gather, generate, or measure environmental data in the field will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications. Field instruments may include a soil gas Gas Tech multi-gas meter, field GC, pH meter, digital thermometer, O_2/CO_2 meter, TVH meter, specific conductivity meter, dissolved oxygen meter, oxidation reduction potential meter, and Hach® spectrophotometer. A summary of calibration frequency and acceptance criteria is presented in Table 6.1and Addendum 1.

6.2 FIELD DATA REDUCTION

During processing of field data, validation checks will be performed by individuals designated by the project manager. The purpose of these checks is to identify outliers; that is, data which do not conform within two standard deviations to the pattern established by other observations. The Students "t" test will be used to identify outliers when the total number of samples is less than 31, and the normal distribution will be used to identify others when the total number of samples is greater than 31. Although outliers may be the result of transcription errors or instrument breakdowns, they may also be manifestations of a greater degree of spatial or temporal variability than expected. Therefore, after an outlier has been identified, a decision must be made concerning its further use. Obvious mistakes in data will be corrected when possible, and the corrected values will be inserted. If the correct value cannot be obtained, the datum may be excluded. An attempt will be made to explain the existence of the outlier. If no plausible explanation can be found for the outlier, it may be excluded, and a note to that effect will be included in the report. Also, an attempt will be made to determine the effect of the outlier both when included in and when excluded from the data set, and the results will be discussed in the report. In addition, the data will be compared against those obtained in previous investigations (where available) and against applicable standards and guidelines.

6.3 REVIEW OF FIELD RECORDS

All field records are evaluated for the following:

TABLE 6.1
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC [a/] PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]	Reporting Limit
SW9050	Conductance	Calibration with potassium chloride standard	Once per day at beginning of testing	± 5%	If calibration is not achieved, check meter, standards, and probe; recalibrate	0.02 µmhos/cm
		Field duplicate	10% of field samples	± 5%	Correct problem, repeat measurement	
SW9040	pH (water)	2-point calibration with pH buffers	Once per day at beginning of testing	± 0.05 pH units for every buffer	If calibration is not achieved, check meter, buffer solutions, and probe; replace if necessary; repeat calibration	pH units
		pH 7 buffer	At each sample location	± 0.1 pH units	Correct problem, recalibrate	
		Field duplicate	10% of field samples	± 0.1 pH units	Correct problem, repeat measurement	
E170.1	Temperature	Field duplicate	10% of field samples	± 1.0°C[c/]	Correct problem, repeat measurement	°C
ASTM[d/] D1498	Oxidation-reduction potential	Calibration with one standard	Once per day at beginning of testing	Two successive readings ± 10 millivolts	Correct problem, recalibrate	pe[e/] units
		Field duplicate	10% of field samples	± 10 millivolts	Correct problem, repeat measurement	
Hach™ 8221	Alkalinity	Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by standard solutions, and optical cell; replace if necessary; repeat calibration check	20.0 mg/L[f/]
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
E360.1	Dissolved oxygen	Calibration check with one standard, and zero meter with sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.5 mg/L
		Field duplicate	10% of field samples	RPD[g/] < 20%	Correct problem, repeat measurement	
HACH™ 8039	Nitrate (NO_3)	Calibration check with one standard, and zero meter w/sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.07 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8040	Nitrite (NO_2)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Hach™ 8146	Ferrous Iron (Fe^{2+})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8034	Manganese	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8131	Hydrogen Sulfide (H_2S)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]	Reporting Limit
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8051	Sulfate (SO_4^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8131	Sulfide (S^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	NA[h]
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Gas Tech Multi-gas Meter	TVH and Methane	Accuracy check, (2 concentration points)	Once per day	± 20 %	Correct problem by checking meter, chech gas standards, correlate with lab analysis	20 ppmv
		Field duplicate	10% of field samples	± 20 %	Correct problem, repeat measurement	
Gas Tech Multi-gas Meter	Oxygen, Carbon Dioxide	Calibration check with ambient air and one standard	Once per day at beginning of testing	± 10 %	Correct problem by checking meter, gas standards, and reaction cell; replace if necessary; repeat calibration check	0.5 %
		Accuracy check, (2 concentration points)	Once per day	± 10 %	Correct problem by checking meter, gas standard , and reaction cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

a/ QC = quality control.
b/ All corrective actions will be documented, and the records will be maintained by the prime contractor.
c/ °C = degrees Celsius.
d/ ASTM = American Society for Testing and Materials.
e/ pe = potential platinum electrode.
f/ mg/L = milligrams per liter.
g/ RPD = relative percent difference.
h/ NA = not applicable.

Table 6.1 Field Screening Method Analytical Protocol Summary of QC Procedures

Completeness of field records. The check of field record completeness will ensure that all requirements for field activities have been fulfilled, complete records exist for each field activity, and that the procedures specified in the SAP (or approved as field change requests) were implemented. Field documentation will ensure sample integrity and provide sufficient technical information to recreate each field event. The results of the completeness check will be documented, and environmental data affected by incomplete records will be identified in the technical report.

Identification of valid samples. The identification of valid samples involves interpretation and evaluation of the field records to detect problems affecting the representativeness of environmental samples. For example, field records can indicate whether a well is properly constructed or if unanticipated environmental conditions were encountered during construction. The lithologic and geophysical logs may be consulted to determine if a well is screened only in the water-bearing zone of concern. Records also should note sample properties such as clarity, color, odor, etc. Photographs may show the presence or absence of obvious sources of potential contamination, such as operating combustion engines near a well during sampling. Judgments of sample validity will be documented in the technical report, and environmental data associated with poor or incorrect field work will be identified.

Correlation of data. The results of field tests obtained from similar areas will be correlated. For example, soil gas TVH readings and VOC analysis results may be correlated. The findings of these correlations will be documented, and the significance of anomalous data will be discussed in the technical report.

Identification of anomalous field test data. Anomalous field data will be identified and explained to the extent possible. For example, a water temperature for one well that is significantly higher than any other well temperature in the same aquifer will be explained in the technical report.

Accuracy and precision of field data and measurements. The assessment of the quality of field measurements will be based on instrument calibration records and a review of any field corrective actions. The accuracy and precision of field measurements will be discussed.

Field record review is an ongoing process. Field team leaders will be responsible for ensuring that proper documentation is recorded during each site's sampling activities.

6.4 FIELD DATA VALIDATION AND REPORTING

The contractor analyst will review 100 percent of all screening data prior to reporting. Screening data will constitute all analytical method results from analyses performed in the field laboratory environment. The contractor will determine if their data quality objectives (DQOs) for field data have been met, and also will calculate the percent complete (PC) for field data results.

At a minimum, the review of screening data will focus on the following topics:

- Holding times;

- Method blanks;
- Field instrumentation detection limits;
- Analytical batch control records including calibrations, and spike recoveries;
- Completeness of data; and
- Flag all results with an "S" to denote sample results from field screening versus fixed laboratory results.

Field data will be validated using four different procedures, as described below:

- Routine checks (e.g., looking for errors in identification codes) will be made during the processing of data.
- Internal consistency of a data set will be evaluated. This step will involve plotting the data and testing for outliers.
- Checks for consistency of the data set over time will be performed. This can be accomplished by comparing data sets against gross upper limits obtained from historical data sets, or by testing for historical consistency. Anomalous data will be identified.
- Checks may be made for consistency with parallel data sets. An example of such a check would be comparing data from the same region of the aquifer or volume of soil.

SECTION 7

FIXED-BASE LABORATORY ANALYTICAL PROCEDURES

Application of a specific analytical method depends on the sample matrix and the analytes to be identified. Methods for each of the parameters likely to be included in the analytical program, as well as detection limits, are discussed in the following subsections. All analytical methods are USEPA approved.

7.1 ANALYTICAL METHODS

Analytical procedures will follow the established USEPA and/or American Society for Testing and Materials (ASTM) methods as recommended by AFCEE wherever such methods exist for a specified analyte. All approved methods are presented in Table 7.1. The referenced methods are defined in the following documents:

- USEPA (1983) *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79-020.
- USEPA (1995) *Test Methods for Evaluating Solid Waste, Physical and Chemical Methods*, SW846, 3rd Edition , Update IIB.
- *American Society for Testing and Materials Methods* (ASTM, 1995).

7.1.2 Detection and Quantitation Limits

This section describes the terms, definitions, and formulas that will be used for detection and quantitation limits.

7.1.3 Instrument Detection Limit

The instrument detection limit (IDL) reflects the instrument operating efficiency, not sample preparation or concentration/dilution factors. The IDL is operationally defined as three times the standard deviation of seven replicate analyses of the lowest concentration that is statistically different from a blank. This represents 99-percent confidence that the signal identified is the result of the presence of the analyte, and not random noise.

7.1.4 Method Detection Limit

The method detection limit (MDL) is the lowest concentration at which a specific analyte in a matrix can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero. MDLs are experimentally determined and

TABLE 7.1
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Aromatic Volatile Organics Compounds SW5030A/SW8020A (W[d], S[e])	1,2-Dichlorobenzene	4.0	µg/L[b]	0.004	mg/kg[c]
	1,3-Dichlorobenzene	4.0	µg/L	0.004	mg/kg
	1,4-Dichlorobenzene	3.0	µg/L	0.003	mg/kg
	Benzene	2.0	µg/L	0.002	mg/kg
	Chlorobenzene	2.0	µg/L	0.002	mg/kg
	Ethylbenzene	2.0	µg/L	0.002	mg/kg
	Toluene	2.0	µg/L	0.002	mg/kg
	Xylenes, Total	2.0	µg/L	0.002	mg/kg
Methane SW3810 Modified (W)	Methane	2.0	µg/L	NA[f]	NA
	Ethane	4.0	µg/L	NA	NA
	Ethene	2.0	µg/L	NA	NA
Volatile Organics SW5030A/SW8260A (W, S)	1,1,1,2-Tetrachloroethane	0.5	µg/L	0.003	mg/kg
	1,1,1-Trichloroethane	0.8	µg/L	0.004	mg/kg
	1,1,2,2-Tetrachloroethane	0.4	µg/L	0.002	mg/kg
	1,1,2-Trichloroethane	1.0	µg/L	0.005	mg/kg
	1,1-Dichloroethane	0.4	µg/L	0.002	mg/kg
	1,1-Dichloroethene	1.2	µg/L	0.006	mg/kg
	1,1-Dichloropropene	1.0	µg/L	0.005	mg/kg
	1,2,3-Trichlorobenzene	0.3	µg/L	0.002	mg/kg
	1,2,3-Trichloropropane	3.2	µg/L	0.02	mg/kg
	1,2,4-Trichlorobenzene	0.4	µg/L	0.002	mg/kg
	1,2,4-Trimethylbenzene	1.3	µg/L	0.007	mg/kg
	1,2-Dichloroethane	0.6	µg/L	0.003	mg/kg
	1,2-Dichlorobenzene	0.3	µg/L	0.002	mg/kg
	1,2-Dibromo-3-Chloropropane	2.6	µg/L	0.01	mg/kg
	1,2-Dichloropropane	0.4	µg/L	0.002	mg/kg
	1,2-Dibromoethane	0.6	µg/L	0.003	mg/kg
	1,3,5-Trimethylbenzene	0.5	µg/L	0.003	mg/kg
	1,3-Dichlorobenzene	1.2	µg/L	0.006	mg/kg
	1,3-Dichloropropane	0.4	µg/L	0.002	mg/kg
	1,4-Dichlorobenzene	0.3	µg/L	0.002	mg/kg
	1-Chlorohexane	0.5	µg/L	0.003	mg/kg
	2,2-Dichloropropane	3.5	µg/L	0.02	mg/kg
	2-Chlorotoluene	0.4	µg/L	0.002	mg/kg
	4-Chlorotoluene	0.6	µg/L	0.003	mg/kg
	Benzene	0.4	µg/L	0.002	mg/kg
	Bromobenzene	0.3	µg/L	0.002	mg/kg
	Bromochloromethane	0.4	µg/L	0.002	mg/kg
	Bromodichloromethane	0.8	µg/L	0.004	mg/kg
	Bromoform	1.2	µg/L	0.006	mg/kg
	Bromomethane	1.1	µg/L	0.005	mg/kg
	Carbon Tetrachloride	2.1	µg/L	0.01	mg/kg
	Chlorobenzene	0.4	µg/L	0.002	mg/kg
	Chloroethane	1.0	µg/L	0.005	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Volatile Organics (Cont)	Chloroform	0.3	µg/L	0.002	mg/kg
SW5030A/SW8260A	Chloromethane	1.3	µg/L	0.007	mg/kg
(W, S)	Cis-1,2-Dichloroethene	1.2	µg/L	0.006	mg/kg
	Cis-1,3-Dichloropropene	1.0	µg/L	0.005	mg/kg
	Dibromochloromethane	0.5	µg/L	0.003	mg/kg
	Dibromomethane	2.4	µg/L	0.01	mg/kg
	Dichlorodifluoromethane	1.0	µg/L	0.005	mg/kg
	Ethylbenzene	0.6	µg/L	0.003	mg/kg
	Hexachlorobutadiene	1.1	µg/L	0.005	mg/kg
	Isopropylbenzene	0.5	µg/L	0.008	mg/kg
	m-Xylene	0.5	µg/L	0.003	mg/kg
	Methylene Chloride	0.3	µg/L	0.002	mg/kg
	n-Butylbenzene	1.1	µg/L	0.005	mg/kg
	n-Propylbenzene	0.4	µg/L	0.002	mg/kg
	Naphthalene	0.4	µg/L	0.002	mg/kg
	o-Xylene	1.1	µg/L	0.005	mg/kg
	p-Isopropyltoluene	1.2	µg/L	0.006	mg/kg
	p-Xylene	1.3	µg/L	0.007	mg/kg
	Sec-Butylbenzene	1.3	µg/L	0.007	mg/kg
	Styrene	0.4	µg/L	0.002	mg/kg
	Tricholoroethene	1.0	µg/L	0.01	mg/kg
	Tert-Butylbenzene	1.4	µg/L	0.007	mg/kg
	Tetrachloroethylene	1.4	µg/L	0.007	mg/kg
	Toluene	1.1	µg/L	0.005	mg/kg
	Trans-1,2-Dichloroethene	0.6	µg/L	0.003	mg/kg
	Trans-1,3-Dichloropropene	1.0	µg/L	0.005	mg/kg
	Trichlorofluoromethane	0.8	µg/L	0.004	mg/kg
	Vinyl Chloride	1.1	µg/L	0.009	mg/kg
Semivolatile Organics	1,2,4-Trichlorobenzene	10.0	µg/L	0.7	mg/kg
Base/Neutral	1,2-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
Extractables					
SW3510B/SW8270B (W)	1,3-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
SW3550A/SW8270B (S)	1,4-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
	2,4-Dinitrotoluene	10.0	µg/L	0.7	mg/kg
	2,6-Dinitrotoluene	10.0	µg/L	0.7	mg/kg
	2-Chloronaphthalene	10.0	µg/L	0.7	mg/kg
	2-Methylnaphthalene	10.0	µg/L	0.7	mg/kg
	2-Nitroaniline	50.0	µg/L	3.3	mg/kg
	3-Nitroaniline	50.0	µg/L	3.3	mg/kg
	3.3'-Dichlorobenzidine	20.0	µg/L	1.3	mg/kg
	4-Bromophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	4-Chloroaniline	20.0	µg/L	1.3	mg/kg
	4-Chlorophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	4-Nitroaniline	50.0	µg/L	3.3	mg/kg
	Acenaphthylene	10.0	µg/L	0.7	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Semivolatile Organics Base/Neutral Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S) (Cont)	Acenapthene	10.0	µg/L	0.7	mg/kg
	Anthracene	10.0	µg/L	0.7	mg/kg
	Benz (a) Anthracene	10.0	µg/L	0.7	mg/kg
	Benzo (a) Pyrene	10.0	µg/L	0.7	mg/kg
	Benzo (b) Fluoranthene	10.0	µg/L	0.7	mg/kg
	Benzo (g,h,i) Perylene	10.0	µg/L	0.7	mg/kg
	Benzyl Alcohol	20.0	µg/L	1.3	mg/kg
	Bis (2-Chlorethyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Chloroethoxy) Methane	10.0	µg/L	0.7	mg/kg
	Bis (2-Chloroisopropyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Ethylhexyl) Phthalate	10.0	µg/L	0.7	mg/kg
	Butyl Benzylphthalate	10.0	µg/L	0.7	mg/kg
	Chrysene	10.0	µg/L	0.7	mg/kg
	Di-n-Butylphthalate	10.0	µg/L	0.7	mg/kg
	Di-n-Octylphthalate	10.0	µg/L	0.7	mg/kg
	Dibenz (a,h) Anthracene	10.0	µg/L	0.7	mg/kg
	Dibenzofuran	10.0	µg/L	0.7	mg/kg
	Diethyl Phthalate	10.0	µg/L	0.7	mg/kg
	Dimethly Phthalate	10.0	µg/L	0.7	mg/kg
	Fluoranthene	10.0	µg/L	0.7	mg/kg
	Fluorene	10.0	µg/L	0.7	mg/kg
	Hexachlorobenzene	10.0	µg/L	0.7	mg/kg
	Hexachlorobutadiene	10.0	µg/L	0.7	mg/kg
	Hexachlorocyclopentadiene	10.0	µg/L	0.7	mg/kg
	Hexachloroethane	10.0	µg/L	0.7	mg/kg
	Indeno (1,2,3-cd) Pyrene	10.0	µg/L	0.7	mg/kg
	Isophorone	10.0	µg/L	0.7	mg/kg
	n-Nitrosodiphenylamine	10.0	µg/L	0.7	mg/kg
	n-Nitrosodi-n-Propylamine	10.0	µg/L	0.7	mg/kg
	Naphthalene	10.0	µg/L	0.7	mg/kg
	Nitrobenzene	10.0	µg/L	0.7	mg/kg
	Phenanthrene	10.0	µg/L	0.7	mg/kg
	Pyrene	10.0	µg/L	0.7	mg/kg
Semivolatile Organics Acid Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S)	2,4,5-Trichlorophenol	50.0	µg/L	3.3	mg/kg
	2,4,6-Trichlorophenol	10.0	µg/L	0.3	mg/kg
	2,4-Dichlorophenol	10.0	µg/L	0.3	mg/kg
	2,4-Dimethylphenol	10.0	µg/L	0.3	mg/kg
	2,4-Dinitrophenol	50.0	µg/L	3.3	mg/kg
	2-Chlorophenol	10.0	µg/L	0.3	mg/kg
	2-Methylphenol	10.0	µg/L	0.3	mg/kg
	2-Nitrophenol	10.0	µg/L	0.3	mg/kg
	4,6-Dinitro-2-Methylphenol	50.0	µg/L	3.3	mg/kg
	4-Chloro-3-Methylphenol	20.0	µg/L	1.3	mg/kg
	4-Methylphenol	10.0	µg/L	0.3	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water PQL[a]	Water Unit	Soil PQL	Soil Unit
	4-Nitrophenol	50.0	µg/L	1.6	mg/kg
Semivolatile Organics Acid Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S) (Cont)	Benzoic Acid	50.0	µg/L	1.6	mg/kg
	Pentachlorophenol	50.0	µg/L	3.3	mg/kg
	Phenol	10.0	µg/L	0.3	mg/kg
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW3550A/SW8310 (S)	Acenaphthene	18.0	µg/L	1.2	mg/kg
	Acenaphthylene	23.0	µg/L	1.54	mg/kg
	Anthracene	6.6	µg/L	0.44	mg/kg
	Benz (a) Anthracene	0.13	µg/L	0.009	mg/kg
	Benzo (a) Pyrene	0.23	µg/L	0.015	mg/kg
	Benzo (b) Fluoranthene	0.18	µg/L	0.012	mg/kg
	Benzo (g,h,i) Perylene	0.76	µg/L	0.05	mg/kg
	Benzo (k) Fluoranthene	0.17	µg/L	0.011	mg/kg
	Chrysene	1.5	µg/L	0.1	mg/kg
	Dibenzo (a,h) Anthracene	0.3	µg/L	0.02	mg/kg
	Fluoranthrene	2.1	µg/L	0.14	mg/kg
	Fluorene	2.1	µg/L	0.14	mg/kg
	Indeno (1,2,3-c,d) Pyrene	0.43	µg/L	0.03	mg/kg
	Naphthalene	18.0	µg/L	1.2	mg/kg
	Phenanthrene	6.4	µg/L	0.42	mg/kg
	Pyrene	2.7	µg/L	0.18	mg/kg
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S)	Aluminum	0.5	mg/L[g]	50.0	mg/kg
	Antimony	0.4	mg/L	40.0	mg/kg
	Arsenic	0.6	mg/L	60.0	mg/kg
	Barium	0.02	mg/L	2.0	mg/kg
	Beryllium	0.003	mg/L	0.3	mg/kg
	Cadmium	0.04	mg/L	4.0	mg/kg
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S) (Cont)	Calcium	0.1	mg/L	10.0	mg/kg
	Chromium	0.07	mg/L	7.0	mg/kg
	Cobalt	0.07	mg/L	7.0	mg/kg
	Copper	0.06	mg/L	6.0	mg/kg
	Iron	0.07	mg/L	7.0	mg/kg
	Lead	0.5	mg/L	50.0	mg/kg
	Magnesium	0.3	mg/L	30.0	mg/kg
	Manganese	0.02	mg/L	2.0	mg/kg
	Molybdenum	0.08	mg/L	8.0	mg/kg
	Nickel	0.15	mg/L	15.0	mg/kg
	Potassium	5.0	mg/L	500.0	mg/kg
	Selenium	0.8	mg/L	80.0	mg/kg
	Silver	0.07	mg/L	7.0	mg/kg
	Sodium	0.3	mg/L	30.0	mg/kg
	Thallium	0.4	mg/L	40.0	mg/kg
	Vanadium	0.08	mg/L	8.0	mg/kg
	Zinc	0.02	mg/L	2.0	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
SW3020A/SW7421 (W)	Lead	0.005	mg/L	0.5	mg/kg
SW3050A/SW7421 (S)	Lead				
SW3020A/SW7131 (W)	Cadmium	0.001	mg/L	0.1	mg/kg
SW3050A/SW7131 (S)	Cadmium				
Common Anions SW9056	Bromide	0.1	mg/L	0.1	mg/kg
	Chloride	0.2	mg/L	0.2	mg/kg
	Fluoride	0.2	mg/L	0.2	mg/kg
	Nitrate	0.1	mg/L	0.1	mg/kg
	Nitrite	0.4	mg/L	0.1	mg/kg
	Phosphate	0.1	mg/L	0.1	mg/kg
	Sulfate	0.2	mg/L	0.2	mg/kg
E160.1	Total Dissolved Solids	10.0	mg/L	NA	NA
E160.2	Total Suspended Solids	5.0	mg/L	NA	NA
E310.1	Alkalinity	10.0	mg/L	NA	NA
E353.1	Nitrogen, Nitrate/Nitrite	0.1	mg/L	NA	NA
SW9050	Conductance	NA	NA	NA	NA
SW9040	pH	NA	NA	NA	NA

SOURCE: AFCEE QAPP, Version 1.1, February 1996

[a] PQLs = practical quantitation limits. PQLs are equal to the project reporting limits.
[b] µg/L = micrograms per liter.
[c] mg/kg = milligrams per kilogram.
[d] W = water.
[e] S = soil.
[f] NA = not applicable.
[g] mg/L = milligrams per liter.

7.1(cont)

Table ~~7.2.8-1~~. PQLs for Method SW8081

Parameter/Method	Analyte	Water PQL	Water Unit	Soil PQL	Soil Unit
Organochlorine Pesticides	α-BHC	0.35	µg/L	0.019	mg/kg
and PCBs	β-BHC	0.23	µg/L	0.033	mg/kg
SW3510B/SW8081 (W)	δ-BHC	0.24	µg/L	0.011	mg/kg
SW3550A/SW8081 (S)	γ-BHC (Lindane)	0.25	µg/L	0.020	mg/kg
	α-Chlordane	0.80	µg/L	0.015	mg/kg
	γ-Chlordane	0.37	µg/L	0.015	mg/kg
	4,4'-DDD	0.50	µg/L	0.042	mg/kg
	4,4'-DDE	0.58	µg/L	0.025	mg/kg
	4,4'-DDT	0.81	µg/L	0.036	mg/kg
	Aldrin	0.34	µg/L	0.022	mg/kg
	Dieldrin	0.44	µg/L	0.035	mg/kg
	Endosulfan I	0.30	µg/L	0.021	mg/kg
	Endosulfan II	0.40	µg/L	0.024	mg/kg
	Endosulfan Sulfate	0.35	µg/L	0.036	mg/kg
	Endrin	0.39	µg/L	0.036	mg/kg
	Endrin Aldehyde	0.50	µg/L	0.016	mg/kg
	Heptachlor	0.40	µg/L	0.020	mg/kg
	Heptachlor Epoxide	0.32	µg/L	0.021	mg/kg
	Methoxychlor	0.86	µg/L	0.057	mg/kg
	PCB-1016	1.00	µg/L	0.70	mg/kg
	PCB-1221	1.00	µg/L	0.70	mg/kg
	PCB-1232	1.00	µg/L	0.70	mg/kg
	PCB-1242	1.00	µg/L	0.70	mg/kg
	PCB-1248	1.00	µg/L	0.70	mg/kg
	PCB-1254	1.00	µg/L	0.70	mg/kg
	PCB-1260	1.00	µg/L	0.70	mg/kg
	Toxaphene	0.50	µg/L	0.57	mg/kg

7.1 (cont)
Table ~~7.2.8-2~~. QC Acceptance Criteria for Method SW8081

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8081	α-BHC	75–125	≤ 30	65–135	≤ 50
	β-BHC	51–125	≤ 30	41–133	≤ 50
	δ-BHC	75–126	≤ 30	65–136	≤ 50
	γ-BHC (Lindane)	73–125	≤ 30	63–130	≤ 50
	α-Chlordane	41–125	≤ 30	31–135	≤ 50
	γ-Chlordane	41–125	≤ 30	31–133	≤ 50
	4,4-DDD	48–136	≤ 30	38–146	≤ 50
	4,4-DDE	45–139	≤ 30	35–149	≤ 50
	4,4-DDT	34–143	≤ 30	25–153	≤ 50
	Aldrin	47–125	≤ 30	37–126	≤ 50
	Dieldrin	42–132	≤ 30	32–142	≤ 50
	Endosulfan I	49–143	≤ 30	39–153	≤ 50
	Endosulfan II	75–159	≤ 30	65–169	≤ 50
	Endosulfan Sulfate	46–141	≤ 30	36–151	≤ 50
	Endrin	43–134	≤ 30	33–144	≤ 50
	Endrin Aldehyde	75–150	≤ 30	65–160	≤ 50
	Heptachlor	45–128	≤ 30	35–138	≤ 50
	Heptachlor Epoxide	53–134	≤ 30	43–144	≤ 50
	Methoxychlor	73–142	≤ 30	63–152	≤ 50
	PCB-1016	54–125	≤ 30	44–127	≤ 50
	PCB-1221	41–126	≤ 30	31–136	≤ 50
	PCB-1232	41–126	≤ 30	31–136	≤ 50
	PCB-1242	39–150	≤ 30	29–160	≤ 50
	PCB-1248	41–126	≤ 30	31–136	≤ 50
	PCB-1254	29–131	≤ 30	25–141	≤ 50
	PCB-1260	41–126	≤ 30	31–136	≤ 50
	Toxaphene	41–126	≤ 30	31–136	≤ 50
	Surrogates:				
	DCBP	34–133		25–143	
	TCMX	45–125		35–135	

AIR TOXICS LTD.

SAMPLE NAME: 0

ID#: 0-01A

EPA METHOD TO-14 GC/MS Full Scan

File Name:	Date of Collection: 1/0/00
Dil. Factor: 1	Date of Analysis:

Compound	Det. Limit (ppbv)	Amount (ppbv)
Freon 12	0.5	Not Detected
Freon 114	0.5	Not Detected
Chloromethane	0.5	Not Detected
Vinyl Chloride	0.5	Not Detected
Bromomethane	0.5	Not Detected
Chloroethane	0.5	Not Detected
Freon 11	0.5	Not Detected
1,1-Dichloroethene	0.5	Not Detected
Freon 113	0.5	Not Detected
Methylene Chloride	0.5	Not Detected
1,1-Dichloroethane	0.5	Not Detected
cis-1,2-Dichloroethene	0.5	Not Detected
Chloroform	0.5	Not Detected
1,1,1-Trichloroethane	0.5	Not Detected
Carbon Tetrachloride	0.5	Not Detected
Benzene	0.5	Not Detected
1,2-Dichloroethane	0.5	Not Detected
Trichloroethene	0.5	Not Detected
1,2-Dichloropropane	0.5	Not Detected
cis-1,3-Dichloropropene	0.5	Not Detected
Toluene	0.5	Not Detected
trans-1,3-Dichloropropene	0.5	Not Detected
1,1,2-Trichloroethane	0.5	Not Detected
Tetrachloroethene	0.5	Not Detected
Ethylene Dibromide	0.5	Not Detected
Chlorobenzene	0.5	Not Detected
Ethyl Benzene	0.5	Not Detected
m,p-Xylene	0.5	Not Detected
o-Xylene	0.5	Not Detected
Styrene	0.5	Not Detected
1,1,2,2-Tetrachloroethane	0.5	Not Detected
1,3,5-Trimethylbenzene	0.5	Not Detected
1,2,4-Trimethylbenzene	0.5	Not Detected
1,3-Dichlorobenzene	0.5	Not Detected
1,4-Dichlorobenzene	0.5	Not Detected
Chlorotoluene	0.5	Not Detected
1,2-Dichlorobenzene	0.5	Not Detected
1,2,4-Trichlorobenzene	0.5	Not Detected
Hexachlorobutadiene	0.5	Not Detected

AIR TOXICS LTD.

SAMPLE NAME: 0

ID#: 0-01A

EPA METHOD TO-14 GC/MS Full Scan

File Name:		Date of Collection: 1/0/00
Dil. Factor:	1	Date of Analysis:

Compound	Det. Limit (ppbv)	Amount (ppbv)
Propylene	2	Not Detected
1,3-Butadiene	2	Not Detected
Acetone	2	Not Detected
Carbon Disulfide	2	Not Detected
2-Propanol	2	Not Detected
trans-1,2-Dichloroethene	2	Not Detected
Vinyl Acetate	2	Not Detected
Chloroprene	2	Not Detected
2-Butanone (Methyl Ethyl Ketone)	2	Not Detected
Hexane	2	Not Detected
Tetrahydrofuran	2	Not Detected
Cyclohexane	2	Not Detected
1,4-Dioxane	2	Not Detected
Bromodichloromethane	2	Not Detected
4-Methyl-2-pentanone	2	Not Detected
2-Hexanone	2	Not Detected
Dibromochloromethane	2	Not Detected
Bromoform	2	Not Detected
4-Ethyltoluene	2	Not Detected
Ethanol	2	Not Detected
Methyl t-Butyl Ether (MTBE)	2	Not Detected
Heptane	2	Not Detected

Container Type: 0

Surrogates	% Recovery	Method Limits
Octafluorotoluene		70-130
Toluene-d8		70-130
4-Bromofluorobenzene		70-130

Table 7.1 Practical Quantitation Limits

Table (C)

Table (C)

Table (C)

Table (C)

add four additional spacer papers

verified for each target analyte of the methods in the sampling program. The laboratory will determine MDLs for each analyte and matrix type prior to analysis of project samples. MDLs are based on the results of seven matrix spikes at the estimated MDL, and are statistically calculated in accordance with the Title 40, Code of Federal Regulations Part 136 (40 CFR 136). The standard deviation of the seven replicates is determined and multiplied by 3.14 (i.e., the 99-percent confidence interval from the one-sided Students T-test). MDLs must be determined annually as a minimum. The MDLs to be used are intended to allow that both nondetects and detects will be usable to the fullest extent possible for the project.

7.1.5 Project Reporting Limit

To define analytical data reporting limits that meet project DQOs, potential risk-based screening criteria were identified. State-specified "clean closure" concentrations, risk-based preliminary remediation goals (PRGs), regulatory concentrations, or other relevant soil, groundwater, and surface water action levels will be reviewed to identify the most stringent comparison criteria for each matrix likely to be applicable. The project reporting limits (PRLs), listed as the practical quantitation limits (PQL) in Table 7.1, will be reviewed in comparison to the risk-based screening criteria.

The PRL is equivalent to the current PQL guidance listed in the AFCEE (1996) QAPP. Because the project remediation goals are developed for risk-based site closure, all sample results will be the reported at or above the MDL for each analyte. All results above the MDL but below the PQL will be qualified in the data deliverable from the laboratory with a "FJ" flag. The "FJ" flag will denote the sample result as below the PQL (see Section 7.6.2). Where practical, MDLs must be lower than the risk-based criterion determined for the project. Laboratories must verify the PRLs by analyzing a standard at or below the PRL within the calibration curve.

All analytical results for soils (both nondetected and detected) will be reported on a dry-weight basis (i.e., corrected for moisture content). The moisture content for each soil sample will be reported. The equation for moisture content given for the SW-846 Method SW3550 is as follows:

$$\frac{\text{Initial Weight - Dried Weight}}{\text{Initial Weight}} \times 100 = \text{\% moisture}$$

The result of the sample on a dry-weight basis is as follows:

$$\frac{\text{Result of analysis on wet weight basis}}{100 - \text{\% Moisture}} = \text{Result of analysis on a dry-weight basis}$$

7.1.6 Sample Quantitation Limit

Sample quantitation limits (SQLs) are defined as the MDL multiplied by the dilution factor (DF) required to analyze the sample, and corrected for moisture or sample size. These adjustments may be due to matrix effects or to the high concentrations of some analytes. For example, if an analyte is present at a concentration that is greater than the linear range of the analytical method, the sample must be diluted for accurate

quantitation. The DF raises the reporting limit, which then becomes the SQL. Because the reported SQLs take into account sample characteristics and analytical adjustments, they are the most relevant quantitation limits for evaluating nondetected chemicals.

7.1.7 Reporting Units

The following are the prescribed reporting units for all analytical methods:

Soil and sediment samples - organics: micrograms per kilogram (µg/kg), dry-weight basis;

Soil and sediment samples - inorganics/metals: milligrams per kilogram (mg/kg), dry-weight basis;

Water samples - inorganics/metals: milligrams per liter (mg/L); and

Water samples - organics: micrograms per liter (µg/L).

7.2 LABORATORY QUALITY CONTROL DATA

Laboratory QC data are necessary to determine the precision and accuracy of the analyses, confirm matrix interferences, and demonstrate target compound contamination of sample results. QC samples will be analyzed routinely by the analytical laboratory as part of the laboratory QC procedures. Contract laboratories performing definitive data quality analyses require a more stringent QC program than those performing screening-level data quality analyses. Definitions for QC samples are presented below. Frequency and acceptance requirements are defined in Table 7.2. All precision and accuracy control limit criteria are defined in Table 1.1.

7.2.1 Holding Time

Holding times for sample extraction and/or analysis as required by the methods will be met for all samples. The holding time is calculated from the date and time of sample collection to the time of sample preparation and/or analysis. All sample analyses to include dilutions and second-column confirmation will meet the required holding times. Results for samples exceeding holding time will be qualified as unusable (flagged "R"). Table 7.3 defines applicable method-specific analytical holding times.

7.2.3 Method Blanks

Method blanks are designed to detect contamination of the field samples in the laboratory environment. Method blanks verify that interferences caused by contaminants in solvents, reagents, glassware, or in other sample processing hardware are known and minimized. The method blank will be ASTM Type II water (or equivalent) for water samples, and a purified solid matrix (Ottawa sand or equivalent) for soil samples. The concentration of target compounds in the blanks must be less than

TABLE 7.2
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Aromatic Volatile Organic Compounds SW8020A and Alcohols SW8015B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c/] < 20% for CFs[d/] or Rfs[e/] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL[f/]	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS[g/] for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Aromatic Volatile Organic Compounds SW8020A and Alcohols SW8015B (cont)	MDL[h/] study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD[i/]	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Results reported between MDL and PRL	None	None	None
Volatile Organics SW8260A	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs[j/] average RF $\geq$ 0.30[k/]; and RSD for all calibration analytes $\leq$ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF $\geq$ 0.30, and CCCs[l/] < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Volatile Organics SW8260A (cont)	Check of mass spectral ion intensities using BFB[m/]	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS[n/]	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP[o/] area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometer or GC[p/] for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then reextract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Semi-volatile Organics SW8270B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs average RF ≥ 0.05; and RSD for all calibration analytes ≤ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Semi-volatile Organics SW8270B (cont)	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF ≥ 0.05; and CCCs < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Check of mass spectral ion intensities using DFTPP	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometry or GC for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Semi-volatile Organics SW8270B (cont)	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c/] < 20% for CFs[d/] or Rfs[e/] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Confirmation [b/]	100% for all positive results	Same as for initial or primary analysis	Same as for initial or primary analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
ICP Metals SW6010A and SW6010 Trace analyses	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Highest calibration standard	Before beginning a sample run	All analytes within ±5% of expected value	Correct problem then repeat initial calibration
	Calibration blank	After every 10 samples and at end of the analysis sequence	No analyte detected >PQL.	Repeat twice, and average results; if average is not within ±3 standard deviations of background mean, terminate analysis; locate and correct problem; reanalyze previous 10 samples
	Continuing calibration verification (Instrument Check Standard)	After every 10 samples and at the end of the analysis sequence	All analyte(s) within ±10% of expected value	Repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
ICP Metals SW6010A and SW6010 Trace analyses (cont)	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	Interference check solution (ICS)	At the beginning and end of an analytical run or twice during an 8 hour period, whichever is more frequent	Within ±20% of expected value	Terminate analysis; correct problem; reanalyze ICS, reanalyze all affected samples
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Dilution test	Each new sample matrix	1:4 dilution must agree within ±10% of the original determination	Perform post-digestion spike addition
	Post-digestion spike addition	When dilution test fails	Recovery within 75-125% of expected results	Correct problem then reanalyze post-digestion spike addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration	No analyte detected > PRL	Correct problem then reanalyze calibration blank and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-phosphorus Pesticides SW8141A	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c/] < 20% for CFs[d/] or Rfs[e/] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Organo-phosphorus Pesticides SW8141A (cont)	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Chlorinated Herbicides SW8151	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c/] < 20% for CFs[d/] or Rfs[e/] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Chlorinated Herbicides SW8151 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-chlorine Pesticides and PCBs SW8081	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Organo-chlorine Pesticides and PCBs SW8081 (cont)	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Breakdown check (Endrin and DDT)	Daily prior to analysis of samples	Degradation ≤20%	Repeat breakdown check
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	%RSD < 20% or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Initial calibration verification	Daily, before sample analysis	All concentration levels of gasoline-range organics within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All concentration levels within ±15% of initial calibration	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No TPH detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria,	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified (cont)	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Mercury SW7470 and SW7471	Initial multipoint calibration (minimum 5 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration, every 10 samples, and ending	No analyte detected > PRL	Correct problem then reanalyze calibration blank and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Mercury SW7470 and SW7471 (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Common Anions E300.0	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±10% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Common Anions E300.0 (cont)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Hexavalent Chromium SW7196	Multipoint calibration curve (minimum three standards and a blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	After each new stock standard preparation	Chromium within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 15 samples and at the end of the analysis sequence	Chromium within ±20% of expected value	Correct problem then repeat initial calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration
	Verification check to ensure lack of reducing condition and/or interference	Once for every sample matrix analyzed	Spike recovery between 85-115%	If check indicates interference, dilute and reanalyze sample persistent interference indicates the need to use and alternate method

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Hexavalent Chromium SW7196 (Cont)	MDL study	Once per year	Detection limits established shall be < the PQLs	None
	Method blank	One per analytical batch	No analyte detected > PQL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PQL	None	None	None
Total Petroleum Hydrocarbons E418.1	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±5% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Total Petroleum Hydrocarbons E418.1 (Cont)		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

a/ QC = quality control.
b/ All corrective actions associated with project work will be documented, and all records will be maintained by the laboratory.
c/ RSD = relative standard deviation.
d/ CF = control factor.
e/ RF = response factor.
f/ PRL = project reporting limit.
n/ IS = internal standard.
o/ EICP = extracted ion current profile.
p/ GC = gas chromatograph.

g/ LCS = laboratory control sample.
h/ MDL = method detection limit.
i/ MS/MSD = matrix spike/matrix spike duplicate.
j/ SPCC = system performance check compound.
k/ ≤30% = except for >0.10 for bromoform and >0.01 for chloromethane and 1,1-dichloroethane.
l/ CCC = continuing calibration check.
m/ BFB = 4-bromofluorobenzene.

TABLE 7.3
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Alkalinity	E310.2	P, G	4°C	50 ml	14 days
Common Anions	E300.0	P, G	4°C	50 ml	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^- and PO_4^{-3}
Filterable Residue	E160.1	P, G	4°C	100 ml	7 days
Nonfilterable Residue	E160.2	P, G	4°C	100 ml	7 days
Hydrogen Ion (pH)	SW9040/ SW9045	P, G	4°C	50 ml or 4 ounces	Analyze immediately
Ammonia, Nitrogen	E350.1	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Nitrogen, Nitrate/Nitrite	E353.2	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Cadmium	SW7131A	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Mercury	SW7470/ SW7471	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	28 days (water and soil)
Metals[d/] (except Cadmium and Mercury)	SW6010A and SW7XXX[e/]	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Total Petroleum Hydrocarbons (TVH)-Gasoline	SW8015 (modified)	G, Teflon®-lined septum, T	4°C, HCl to pH < 2	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TEH)-Diesel	SW8015 (modified)	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile Aromatics	SW8020A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Volatile Halocarbons	SW8010A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Formaldehyde	SW8315	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Ethylene Glycol	SW8315 modified	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Alcohol Scan	SW8015B	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TPH)	E418.1	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Chlorinated Herbicides	SW8151	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organochlorine Pesticides and Polychlorinated Biphenyls (PCBs)	SW8081	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organophosphorus Pesticides	SW8141A	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Semivolatile Organics	SW8270B	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Volatile organics	SW8260A/8240	G, Teflon®-lined septum, T	4°C, 0.008% $Na_2S_2O_3$ (HCl to pH < 2 for volatile aromatics by SW8240 and SW8260)[b]	3 x 40 ml or 4 ounces	14 days (water and soil)
Polynuclear Aromatic Hydrocarbons (PAHs)	SW8310	G, Teflon®-lined cap, T	4°C, store in dark, 0.008% $Na_2S_2O_3$	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Methyl Carbamate Herbicides	SW8318	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Lead (paint)	SW7421	P, G	4°C	2 ounces	180 days
Asbestos	NIOSH 7400	P, G	4°C	2 ounces	NA[f/]

a/ Polyethylene (P); glass (G); brass sleeves in the sample barrel (T).
b/ No pH adjustment for soil.
c/ Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.
d/ All metals collected for a dissolved portion analysis will be filtered in the field prior to preservation.
e/ SW7XXX is all graphite furnace atomic absorption methods, SW7421, 7060, 7131, and 7740.
f/ Not applicable.

Table 7.2 Summary of Calibrationa nd QC Procedures

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.2 (C)

Table 7.3 Requirements for Containers, Preservation Techniques, Sample Volumes, and Holding Times

Table 7.3 (C)

Table 7.3 (C)

Table 7.3 (C)

or equal to the PRL (Table 7.1). Exceptions are not made for common laboratory contaminants. If the blank contaminant concentration is not less than the specified limit, then the source of contamination will be identified, and corrective action will be taken. SQLs and detection limits will not be raised because of blank contamination. Analytical data will not be corrected for presence of analytes in blanks.

7.2.4 Laboratory Control Samples

Laboratory control samples (LCSs) are blank spikes made from clean laboratory-simulated matrices (reference method blank matrices) spiked with known concentrations of all target analytes of interest at levels approximately 10 times the MDLs. The LCS is carried through the complete sample preparation and analysis procedures. LCSs are designed to check the instrument and method accuracy. An LCS will be analyzed with every analytical batch. Failure of the LCS to meet %R criteria listed in Table 1.1 requires corrective action before any further analyses can continue. All sample results associated with the out-of-control LCS must be reanalyzed after control has been reestablished.

7.2.5 Surrogate Spike Analyses

Surrogate spike analyses are used to determine the efficiency of analyte recovery in sample preparation and analysis in relation to sample matrix. Calculated %R of the spike is used to measure the accuracy of the analytical method for an individual sample. A surrogate spike is prepared by adding to an environmental sample (before extraction) a known concentration of a compound similar in type to the target analytes (i.e., a surrogate compound) to be analyzed for organic target compounds. Surrogate compounds as specified in the methods will be added to all samples analyzed, including method blanks, MS/MSDs, LCSs, field samples, and duplicate samples.

7.2.6 Matrix Spike/Matrix Spike Duplicate

Matrix spike (MS) samples are designed to check the accuracy of the analytical procedures for the sample matrix by analyzing a field sample spiked in the laboratory with a known standard solution containing all the target analytes. A matrix spike duplicate (MSD) is the second of a pair of laboratory MS samples. The MSDs are designed to check the precision and accuracy of analytical procedures by sample matrix.

One MS/MSD pair will be collected for every group of 20 project samples of similar matrix. Field blanks or duplicates are not to be used as MS/MSDs. If surrogate and target analyte compounds concentrations are out of control in the MS/MSD, but the associated accuracy and precision are in control in the LCS, then the out-of-control situation will be attributed to a matrix interference. If the laboratory system is shown to be out-of-control (i.e., if the LCS is out-of-control), then re-extraction and reanalysis will be required. The laboratory will report the data from any reanalysis that is performed.

7.2.7 Analytical Batches

Analytical batches will be designated in the laboratory at a minimum of one batch per sample delivery group (SDG). Each SDG will be comprised of a maximum of 20 project samples of similar matrix collected within a 7-day period. Included in each SDG of 20

(or fewer) samples per analytical method will be an analytical batch identification number. This identification number will clearly allow a reviewer to determine the association between field samples and QC samples. Analytical batches also will be inclusive of preparation lots and calibration periods.

7.2.8 Retention Times

Retention time (RT) is the amount of time required for a target compound to elute from the chromatographic column, and the instrument detector to record a signal response. The RT window is the allowable deviation from the true expected RT for any one compound. A peak response within this RT window will constitute a positive detection for that compound. RT windows are QC criteria for all gas chromatograph (GC) and high-performance liquid chromatography (HPLC) methods. RT windows are determined through replicate analyses of a standard over multiple days. The calculation of RT windows is described in USEPA (1995) Method SW8000A. Corrective action is required when the RT windows are out of control.

7.2.9 Internal Standards

Internal standards (ISs) are compounds of known concentrations used to quantitate the concentrations of target detections in field and QC samples. ISs are added to all samples after sample extraction or preparation. Because of this, ISs provide for the accurate quantitation of target detections by allowing for the effects of sample loss through extraction, purging, and/or matrix effects. ISs are used for any method requiring an IS calibration. Corrective action is required when ISs are out of control.

7.2.10 Interference Check Standard

The interference check standard (ICS) is used to verify the background and interelement correction factors for metals in method SW6010A. The ICS is analyzed at the beginning and end of each analytical sequence. Method-specific acceptance limits listed in Table 1.1 will apply.

7.2.11 Second Column Confirmation

Quantitative confirmation of results at or above the PQL for samples analyzed by GC or HPLC will be required and will be completed within the method-required holding times. For GC methods, a second column is used for confirmation. For HPLC methods, a second column or a different detector is used. The result of the first column/detector will be the result reported.

7.2.12 Control Limits

The control limits associated with all method QC will follow guidance established in the AFCEE (1996) QAPP. For methods not defined in the AFCEE (1996) QAPP (e.g., SW3810 modified for methane), the acceptance criterion in Table 1.1 is listed as suggested guidance.

7.2.13 Calibration Requirements

Analytical instruments will be calibrated in accordance with the analytical methods. All analytes reported will be present in the initial and continuing calibrations, and these calibrations must meet the acceptance criteria specified in Table 1.1. Records of standard preparation and instrument calibration will be maintained by the contract laboratory. Records will unambiguously trace the preparation of standards and their use in calibration and quantitation of sample results. Calibration standards will be traceable to standard materials.

Analyte concentrations are determined with either calibration curves or response factors (RFs). For GC and GC/mass spectroscopy (MS) methods, when using RFs to determine analyte concentrations, the average RF from the initial five-point calibration will be used. The continuing calibration will not be used to update the RFs from the initial five-point calibration.

7.2.14 Standard Materials

Standard materials used in calibration and to prepare samples will be traceable to National Institute of Standards and Technology (NIST), USEPA, American Association of Laboratory Accreditation (A2LA) or other equivalent approved source, if available. The standard materials will be current, in accordance with the following expiration policy: The expiration dates for ampulated solutions will not exceed the manufacturer's expiration date or one year from the date of receipt, whichever occurs first. Expiration dates for laboratory-prepared stock and diluted standards will be no later than the expiration date of the stock solution or material, or the date calculated from the holding time allowed by the applicable analytical method, whichever occurs first. The laboratory will label standard and QC materials with expiration dates.

7.3 SAMPLE CUSTODY REQUIREMENTS

Sample custody begins in the field at the time of collection and continues throughout the laboratory analytical process. COC forms will be prepared at the time sample collection and will accompany the samples through the laboratory sample processing. To facilitate the documentation of sample custody, the laboratory will track the progress of sample preparation, analysis, and report preparation. Samples received by the laboratory will be checked carefully for label identification, COC forms, and any discrepancies. The laboratory will also note physical damage, incomplete sample labels, incomplete paperwork, discrepancies between sample labels and paperwork, broken or leaking containers, and inappropriate caps or bottles. On the day of receipt of samples from the contractor, the laboratory will send signed facsimile copies of all COCs and sample log-in receipt forms to the contractor. All discrepancies and/or potential problems (e.g., lack of sample volume) will be discussed immediately with the contractor's project task manager.

The laboratory sample custodian will be required to provide a report to the contractor of any problems observed with any of the samples received. This report will also document the condition of samples, sample numbers received, corresponding laboratory numbers, and the estimated date for completion of analysis. The laboratory must receive

written permission from the contractor before sending any samples (originally scheduled to be analyzed at their facility) to another laboratory. Analyses will not be performed on samples whose integrity has been compromised or is suspect.

7.4 SAMPLE HANDLING

Laboratory sample custody will be maintained by the following procedures:

1. The laboratory will designate a sample custodian responsible for maintaining custody of the samples and all associated paperwork documenting that custody.
2. Upon receipt of the samples, the sample custodian will sign the original COC form and compare the analyses requested thereon with the label on each sample container.
3. A qualitative assessment of each sample container will be performed to note any anomalies such as broken or leaking bottles or lack of preservation (e.g., ice melted enroute). This assessment will be recorded as part of the incoming COC procedure.
4. If the COC and samples correlate, and there has been no tampering with the custody seals, the "received by laboratory" box on the COC form will be signed and dated.
5. Care will be exercised to document any labeling or descriptive errors. In the event of discrepancies, breakage, or conditions that could compromise the validity of analyses, the laboratory project coordinator will immediately contact the task manager as part of the corrective action process.
6. Samples will be logged into the laboratory management computer system, which includes a tracking system for extraction and analysis dates. The laboratory will assign a laboratory work number to each sample for identification purposes. The sample custodian will log the laboratory work number and the field sample identification into a laboratory sample custody log. The laboratory sample custody log may either be hard copy or computerized, depending on the laboratory's system.
7. The samples will be stored in a secured area at a temperature of approximately 4 ± 2 degrees Celsius (°C) or cooler (as applicable) until analyses commence. The laboratory log should also contain the laboratory storage cooler number (if applicable) that the sample will be stored in while on the laboratory's premises. Samples will be logged when they are removed and returned from storage for analysis. Samples must be stored in separate coolers from those used to store analytical standards, reagents, and/or QC samples.
8. The samples will be distributed to the appropriate analysts, with names of individuals who receive samples recorded in internal laboratory records.
9. The original COC form will accompany the laboratory report submittal and will become a permanent part of the project records.

10. Data generated from the analysis of samples also must be kept under proper custody by the laboratory.

Upon analysis, a laboratory lot control number will be assigned to the sample. All samples within a given laboratory analysis group (e.g., samples sharing the same laboratory QC measurement samples) will have identical laboratory lot control numbers.

Disposal of sample containers and remaining sample material will be the responsibility of the laboratory. Samples should be disposed of appropriately when all analyses and related QA/QC work are completed.

7.5 SAMPLE IDENTIFICATION AND SAMPLE CUSTODY RECORDS

The laboratory conducting the analysis of the samples will provide the data user with information on the laboratory sample identification system. With knowledge of this laboratory sample identification system, data generated at the laboratory can be tracked by both the laboratory and field sample identification systems.

Each sample will be logged into the laboratory system by assigning it a unique sample number. This laboratory number and the field sample identification number will be recorded on the laboratory report.

7.6 LABORATORY DATA REDUCTION, VALIDATION, AND REPORTING

7.6.1 Review Procedures for Definitive Data

The fixed-base laboratory will review 100 percent of all definitive data prior to reporting. The establishment of detection and control limits will be verified. Any control limits outside of the acceptable ranges specified in the analytical methods will be identified. Any trends or problems with the data will be evaluated. Any laboratory-established detection limits that exceed the established method-specified limits will be identified. The absence of records supporting the establishment of control criteria or detection limits will be noted. Analytical batch QC, calibration check samples, method calibrations, continuing calibration verifications, corrective action reports, the results of reanalysis, sample holding times, sample preservations, and any resampling and analysis all will be evaluated.

Samples associated with out-of-control QC data will be identified in the data package case narrative, and an assessment of the utility of such analytical results will be made. The check of laboratory data completeness will ensure that:

- All samples and analyses specified in the SAP have been processed;
- Complete records exist for each analysis and the associated QC samples; and
- Procedures specified in this SAP have been implemented.

The results of the completeness check will be documented.

An analyst other than the original data processor, will be responsible for reviewing all steps of the data processing. All input parameters, calibrations, and transcriptions will be checked. All manually input, computer-processed data will be checked. Each page of checked data will be signed and dated by the verifier.

QC sample results (LCSs, MS/MSDs, surrogates, initial calibration standards, and continuing calibration standards) are compared against stated criteria for accuracy and precision (Table 7.2). QC data must meet acceptance levels prior to processing the analytical data. If QC standards are not met, the cause will be determined. If the cause can be corrected without affecting the integrity of the analytical data, processing of the data will proceed. If the resolution jeopardizes the integrity of the data, reanalysis will occur.

Decisions to repeat sample collection and analyses may be made by the contractor project manager based on the extent of the deficiencies and their importance in the overall context of the project. Figure 7.1 defines the general flow of sample data from sample shipment to the laboratory to the final report generation by the contractor.

7.6.2 Laboratory Data Reporting Flags

The following qualifiers must be used by the laboratory when reporting sample results.

Qualifier	Description
J	The analyte was positively identified, the quantitation is an estimation.
U	The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F	The analyte was positively identified but the associated numerical value is below the PQL.
R	The data are unusable due to deficiencies in the ability to analyze the sample and meet QC criteria.
B	The analyte was found in an associated blank, as well as in the sample.
M	A matrix effect was present.
T	Tentatively identified compound (using GC/MS)

Figure 7.1

7.6.3 Contractor Data Reporting Flags

The following define the contractor organic and inorganic data validation qualifiers:

- U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is the PRL (e.g., the nondetect level).
- J - The associated value is an estimated quantity.
- R - The data are unusable (Note: analyte may or may not be present).
- UJ - The material was analyzed for but was not detected. The associated value is an estimate and may be inaccurate or imprecise.

7.6.4 Data Validation and Assessment of Usability

Data from QC samples will be assessed by the contractor using the procedures and criteria presented earlier in this section. This assessment will be a continuous process in which QA problems are identified immediately, and the appropriate corrective action is implemented. Additionally, the contractor will assess the usability of analytical data. Any limitations on data use will be expressed quantitatively to the extent practicable and will be documented in any reporting of the data.

This data usability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The outcome of this data review will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined in *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual* (USEPA, 1989) and the *Guidance for Data Useability in Risk Assessment* (USEPA, 1992) will be used as appropriate.

7.6.5 Hard-Copy Data Deliverables

Data deliverables required for the analytical results include both a hard copy and an electronic copy. Hard-copy reporting of analytical results will include analytical results summaries for all field samples, and their associated QA/QC samples. The laboratory will be required to provide two copies of each hard copy data reporting package. Data reporting requirements for hard-copy analytical reports are in Table 7.4 as those items listed with an asterisk.

7.6.6 Electronic Data Deliverables

To facilitate data handling and management, both field and laboratory data will be entered into a computerized format. All data will be delivered to the contractor from the laboratory in the database format specified in the *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook*, Version 2.2, AFCEE, 1991. The laboratory will be responsible for running QC Tools on the analytical data files prior to delivery to the contractor.

TABLE 7.4
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for all methods:	
- Case narrative	Project identification Analytical method description and reference citation. Discussion of unusual circumstances, problems, and nonconformances.
Monthly QA report	Any format to discuss issues which may affect data quality *
- Chain of Custody (COC)	Signed and dated when samples were* received at laboratory
- Dates of sample preparation and analysis (including first run and subsequent runs).	Specific deliverable depends upon* type of analysis
- Quantitation limits achieved.	Specific deliverable depends upon type* of analysis
- Dilution or concentration factors.	Specific deliverable depends upon* type of analysis
- Summary analytical batch report including analytical batch samples, method of analysis, matrix description, date of sample collection and receipt, laboratory identification number of each environmental sample plus identification number of each batch quality control (QC) sample (including Matrix Spike/Matrix Spike Duplicate (MS/MSD), calibration check, etc.).	Any format*
- Method reporting limits.	QC summary report*
- QC limits.	QC summary report*
- Practical Quantitation Limit (PQL) verification standard (weekly).	Any format
- Corrective action reports.	Any format *
- A copy of all raw laboratory analytical data.	Any format (chromatograms, mass spectra and data system printouts)
- Example sample calculation	Any format
- A copy of the sample preparation data form for each method indicating sample identification number, batch identification number, and date of preparation.	Any format (preparation, extraction, or digestion data)
Percent moisture for all soil samples	Any format *

TABLE 7.4 (Concluded)
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for organic analytical methods:	
- Sample data sheets.	Summary information only [a/]*
- Surrogate recoveries.	Summary information only *
- MS/MSD.	Summary information only *
- Method blank analysis.	Summary information only *
- Laboratory control spike (LCS)	Summary information only*
- Instrument performance check (Tuning).	Summary information only
- Degradation/breakdown (SW8080).	Summary information only
- Initial calibration data	Summary information only
- Continuing calibration data.	Summary information only
- Calibration blank data	Summary information only
- Internal standard area and retention time summary data.	Summary information only
- Retention time windows	Summary information only*
- Second-column confirmation. To be done for all compounds that are detected above reporting limit	Summary information only*
- Analysis run log.	No format
Requirements for inorganic analytical methods	
Metals:	
- Sample data sheets.	Summary information only *
- Initial and continuing calibration.	Summary information only
- Method blank, taken through sample preparation.	Summary information only *
- Calibration blank data.	Summary information only
- Interference check sample.	Summary information only
- Laboratory control spike/laboratory control spike duplicate.	Summary information only*
- Matrix spike/matrix spike duplicate.	Summary information only *
- Post-digestion spike sample recovery	Summary information only
- Method of standard additions	Summary information only
- Serial dilutions	Summary information only
- Analysis run logs	No format

* Indicates hard-copy deliverables required for QC summary package of Option 3 and 4.

a\ Summarized results can be in any format that provides the necessary data to completely validate that QC parameter. Example formats are the form equivalents to those defined for the USEPA Contract Laboratory Program (CLP) or SW-846 programs.

The laboratory reporting system will be implemented and tested prior to beginning the sampling. Any problems detected in format will be corrected by laboratory prior to providing any electronic deliverables to the contractor. All data entered into the electronic data files will correspond to the data contained in the original laboratory reports and other documents associated with sampling and the laboratory hard copy data deliverable packages.

7.6.7 Quality Assurance Reports

At monthly intervals beginning with the initiation of sampling activities, the laboratory will submit to the contractor's project task manager an internal QA report that documents laboratory-related QA/QC issues. These reports will include discussions of any conditions adverse or potentially adverse to quality, such as:

- Responses to the findings of any internal or external systems or performance laboratory audits;

- Any laboratory or sample conditions which necessitate a departure from the methods or procedures specified in this SAP;

- Any missed holding times or problems with laboratory QC acceptance criteria; and

- The associated corrective actions taken.

Submittal of QA reports will not preclude earlier contractor notification of such problems when timely notice can reduce the loss or potential loss of quality, time, effort, or expense. Appropriate steps will be taken to correct any QA/QC concerns as they are identified. The QA reports and a summary of the laboratory QA/QC program and results will be included in the final project report.

7.7 CORRECTIVE ACTION

The following procedures have been established to assure that conditions adverse to data quality are promptly investigated, evaluated, and corrected. Adverse conditions may include malfunctions, deficiencies, deviations, and errors.

When a significant condition adverse to data quality is noted at the laboratory, the cause of the condition will be determined, and corrective action will be taken to prevent repetition. Condition identification, cause, reference documents, and corrective action planned will be documented and reported to the contractor QA officer by the laboratory QC coordinator. Following implementation of corrective action, the laboratory QC coordinator will report the actions taken and their results to the contractor project manager and QA officer. A record of the action taken and results will be attached to the data report package. If samples are reanalyzed, the assessment procedures will be repeated, and the control limits will be reevaluated to ascertain if corrective actions have been successful.

Implementation of corrective action is verified by documented follow-up action. All project personnel have the responsibility, as part of the normal work duties, to identify, report, and solicit approval of corrective actions for conditions adverse to data quality.

Corrective actions will be initiated in the following instances:

- When predetermined acceptance criteria are not attained (Tables 7.1, 7.2, and 7.3) (objectives for precision, accuracy, and completeness);
- When the prescribed procedure or any data compiled are faulty;
- When equipment or instrumentation is determined to be faulty;
- When the traceability of samples, standards, or analysis results is questionable;
- When QA requirements have been violated;
- When designated approvals have been circumvented;
- As a result of systems or performance audits;
- As a result of regular management assessments;
- As a result of intralaboratory or interlaboratory comparison studies; and
- At any other instance of conditions significantly adverse to quality.

Laboratory project management and staff, such as QA auditors, document and sample control personnel, and laboratory groups, will monitor work performance in the normal course of daily responsibilities.

The laboratory QC coordinator or designated alternate will audit work at the laboratory. Items, activities, or documents ascertained to be compliant with QA requirements will be documented, and corrective actions will be mandated in the audit report. The contractor QA officer and laboratory QC coordinator will log, maintain, and control the audit findings.

The contractor QA officer and laboratory QC coordinators are responsible for documenting all out-of-control events or non-conformance with QA protocols. The QC checks, their frequency, acceptance criteria, and corrective actions for out-of-control data are summarized in Table 1.1 for each analytical method. A nonconformance report will summarize each nonconformance condition. The laboratory will notify the contractor project manager or QA officer of any laboratory QA/QC nonconformances upon their discovery. Copies of all field change requests and corrective action forms will be maintained in the project files. A stop-work order may be initiated by the contractor if corrective actions are insufficient.

7.7 AUDITS

This section describes participation in external and internal systems audits for AFCEE contractors and laboratories.

7.7.1 System Audits

System audits review laboratory operations and the resulting documentation. An onsite audit ensures that the laboratory has all the personnel, equipment, and internal standard operating procedures (SOPs) needed for performance of contract requirements in place and operating. The system audits ensure that proper analysis documentation procedures are followed, that routine laboratory QC samples are analyzed, and that any nonconformances are identified and resolved.

7.7.2 Internal Audits

The laboratory must conduct internal system audits on a periodic basis. The results of these audits will be documented by the laboratory QC coordinator, and the laboratory will provide the contractor with the results of these internal audits.

7.7.3 External Audits

The contractor project QA officer or designee may conduct an external system audit of the laboratory during the performance project samples. This audit would evaluate the capabilities and performance of laboratory personnel, items, and activities. It also documents the measurement systems and identifies and corrects any deficiencies. The contractor QA manager acts on audit results by documenting deficiencies and informing the contractor project manager of the need for corrective action. The contractor project manager may suspend operations until problems are resolved. If conditions adverse to quality are detected, or if the contractor project manager requests additional audits, additional unscheduled audits may be performed.

In addition to the contractor audit of the laboratory, various state and/or federal agencies may conduct an audit prior to the commencement of the project, and may conduct additional audits as deemed necessary. The frequency and schedule of any such audits will be established by the auditing agency and coordinated directly with the laboratory.

7.7.4 Performance Audits

Laboratory performance audits may be conducted to determine the accuracy and implementation of the SAP by the contractor QA manager or designee prior to initiation of field sampling. Unplanned audits may be implemented if requested by the contractor project manager. In addition to in-house performance audits, the laboratory may also participate in interlaboratory performance evaluation studies for different state or federal agencies. The contractor project QA manager will act to correct any laboratory performance problems.

7.8 PREVENTIVE MAINTENANCE

7.8.1 Procedures

Equipment, instruments, tools, gauges, and other items requiring preventive maintenance will be serviced in accordance with the manufacturers' specified recommendations or written procedures developed by the operators.

7.8.2 Schedules

Manufacturers' procedures identify the schedule for servicing critical items in order to minimize the downtime of the measurement system. It will be the responsibility of the individual operator assigned to a specific instrument to adhere to the instrument maintenance schedule and to promptly arrange any necessary service. Servicing of the equipment, instruments, tools, gauges, and other items will be performed by qualified personnel.

The laboratory will establish logs to record maintenance and service procedures and schedules. All maintenance records will be documented and will be traceable to the specific equipment, instruments, tools, and gauges. Records produced for laboratory instruments will be reviewed, maintained, and filed by the operators at the laboratories.

7.8.3 Spare Parts

A list of critical spare parts will be requested from manufacturers and identified by the operator. These spare parts will be stored for availability and use in order to reduce downtime due to equipment failure and repair.

7.9 SUBCONTRACT LABORATORY SERVICES

The laboratory will assume responsibility for providing all analytical services specified in the laboratory agreement. Should it be agreed in writing that the laboratory may use an additional subcontract laboratory facility, the primary laboratory will supply to the contractor the SOPs, MDL studies, and QA plans for the other laboratories that are used. The laboratory will be responsible for communicating all analytical guidelines and QC requirements of the project to these laboratories. The QA officers from both the primary laboratory and the contractor will monitor the data from subcontract laboratories and correct any QC nonconformances.

SECTION 8

REFERENCES

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ADDENDUM 1

STANDARD OPERATING PROCEDURE FOR FIELD GAS CHROMATOGRAPH

JANUARY 1997

DENVER OFFICE PROCEDURE			
Title: HEADSPACE GAS CHROMATOGRAPHY ANALYSIS OF VOLATILE ORGANIC COMPOUNDS IN WATER USING PHOTOVAC 10S50 PORTABLE GAS CHROMATOGRAPH			
Procedure No.: DE-DQ-SOP-001	**Revision:** 1	**Effective Date:** 6/1/94	**Supersedes Issue Dated:** N/A
Author:	**Date:**	**Approved:**	**Date:**

1.0 PURPOSE

This procedure describes the method to be used for analysis of water sample headspace for volatile organic compounds (VOCs) using the Photovac 10S50 portable gas chromatograph (GC). The method is for determining the relative concentration of selected VOCs at an approximate minimum of 5-part-per-billion (ppb) [5 microgram-per-liter (µg/L)] or higher.

The purpose of the headspace analysis is to screen organic compound contamination in ground water and to determine the extent of contamination. Information obtained from the ground water screening can be used to determine the vertical and lateral extent of an organic plume. The GC results can also serve as a guide for deciding where to locate new monitoring wells.

2.0 SCOPE

This SOP includes quality controls to ensure that the data produced will be U.S. Environmental Protection Agency (EPA) level II in quality. This standard operating procedure (SOP) applies to field sampling screening events only. The primary objective of the method is to provide analytical data in a timely manner to guide ongoing work in the field. Identification of specific target compounds and prior knowledge regarding potential matrix interferences are prerequisites for successful use of the method. The data can be verified by sending a duplicate portion of approximately 10% of the samples to a laboratory for SW8240 or SW8260 analysis.

This method is used to tentatively identify and relatively quantify each of the analytes listed in Table 1. The VOCs will be determined from the headspace above an aqueous sample under static conditions. These compounds will be detected, identified, and quantified using a GC equipped with a photoionization detector (PID). The GC/PID is more sensitive to aromatic than aliphatic hydrocarbons.

The method detection limit studies and the method detection limits determined for each project are recorded in the project logbook. Method detection limits are determined following the procedure described in 40 CFR, Part 136. The reporting limits used for a project must be no lower than the lowest calibration standard used.

The sensitivity of the static headspace technique may be increased by application of heat and agitation to the sample during the analysis to result in additional transfer of VOC from the liquid into the headspace area.

TABLE 1

TARGET ANALYTES

Trichlorofluoromethane	Chloroform
Vinyl chloride	1,1,1-Trichloroethane (TCA)
1,2-Dichloroethane (DCA)	Benzene
1,1-Dichloroethene (1,1-DCE)	cis-1,2-Dichloroethene (DCE)
Chlorobenzene	Ethylbenzene
m,p-xylene	o-xylene
Bromoform	1,1,2,2-Tetrachloroethane

3.0 REQUIREMENTS

Screening waters for organic compounds involves a four-step approach that includes selection of sampling media and depth, sample collection, sample preparation, and sample analysis. Project-specific requirements for the first two steps are specified in the project's Sampling and Analysis Plan (SAP).

4.0 REFERENCES

Photovac Incorporated. *Photovac 10S50 Operating Manual.* Huntington, New York.

U.S. Environmental Protection Agency. 1987. *Method SW3810: Headspace and SW8000 Gas Chromatography; Test Methods for Evaluating Solid Waste, Physical Chemical Methods.* SW846. 3rd Edition. Office of Solid Waste and Emergency Response. December.

Sciver, Charles and Robert Fowler. 1993. *Increasing the Sensitivity of Field Headspace Analysis for Volatile Organic Compounds.* New Jersey Department of Environmental Protection and Energy, Environmental Measurements Section. Trenton, New Jersey. July.

5.0 DEFINITIONS

Headspace Method

The headspace is the vapor region above a liquid sample in a closed vial. The headspace method assumes chemical equilibrium between the compounds in the water and in the gas phase above the solution. Compounds that tend to partition into the headspace have Henry's Law constants greater than $1x\ 10^{-2}$ kPa m^3/mole.

Gas Chromatography

Gas chromatography is an analytical technique in which a known volume of gas is injected into a gas chromatograph. The various organic compounds are separated as they travel through the column of the chromatograph and then are identified as they pass through the photoionization detector where a peak-area signal, proportional to the concentration in the gas, is generated. This peak area is compared to the peak area of a standard solution containing known amounts of the target analytes. Linear relationships between the concentrations in the standard and in the known are assumed.

6.0 PREREQUISITES, EQUIPMENT, AND SUPPLIES

6.1 Analytical Equipment

A. Field Gas Chromatograph
Photovac 10S50 field portable GC equipped with a PID.

1. Lamp - The Photovac 10S50 will be equipped with the appropriate lamp for the project. Optional lamps will include 11.7-eV, 10.0-eV, 9.5-eV, and 8.4-eV lamps. The standard lamp is the 10.6-eV, UHF-excited electrodeless discharge tube. A backup lamp should be available.

2. GC Column - The GC column will be chosen to provide the best resolution and sensitivity for the compounds of interest. The standard

column on the Photovac field GC is a CPSil 5 wide-bore column (10 m x 0.53 mm i.d.; 100 % dimethyl polysiloxane, chemically bonded). This column has a nonpolar phase suitable for separating chlorohydrocarbons, benzene, toluene, and xylene. This capillary column is configured in a precolumn/backflush configuration with a 1-m precolumn and 9-m analytical column. A backup column should be available.

B. Water Bath

A constant-temperature bath manufactured by Precision Co. will be used to provide reproducible and constant temperature (±. 2°C) for the samples. Operating instructions for the bath are given in the manual which was received with the bath.

6.2 Supplies

A. Gas-Tight Syringes

Gas-tight syringes capable of dispensing 10, 25, 100, and 250 microliters of vapors are required. Glass syringes capable of dispensing 10 microliters, 100 microliters, and 1 milliliter of liquid are also required for preparation of the standard samples from the methanol stock solutions.

B. VOA Bottles

Forty-milliliter glass VOA sample bottles with Teflon® seals are required.

C. Volumetric Flasks

Volumetric flasks with Teflon® or ground glass stoppers in volumes of 10, 20, 25, and 50 milliliters are required.

D. Disposable 5-Inch Glass Pasteur Pipettes

E. Propipette and Disposable 25-Milliliter Graduated Pipettes

F. Septa Seal Vials of 1 and 3 Milliliter Capacities and Supporting Rack

G. Purge and Trap Quality Methanol

H. HPLC or ASTM Type-II Quality Water

I. Office Supplies (Notebooks, Sharpies, Pens, Report Forms, Etc.)

J. GC Operating Supplies (Tubing, Septa, Graph Paper, Extra Lamp, Extra Column, Etc.)

K. Reagent Standards for Project's Target Analyte List
Select those target analytes from Table 1 that are of concern for the project and purchase manufacturer-certified solutions in methanol.

L. Ultra High Purity Air (Carrier Gas)

6.3 Training for the Field GC Operator

This method is restricted to use by or under the supervision of an experienced chemist. All operators must receive training in the areas specified in Appendix A.

6.4 Project-Specific Standard Operating Procedure

Additions and modifications shall be made to this SOP to meet the needs of each project.

6.5 Safety Issues

The GC Operator will work with the Field Leader to establish the proper disposal procedures to be followed for the standards prepared for the analysis and for the samples that contain target analytes above detection limits. The carrier gas cylinder shall be fastened to an immovable object. Common laboratory safety rules shall be followed with regard to the use of volatile chemicals and syringes. The field GC Operator shall read the material safety data sheets for the chemicals being used in the analysis. Manufacturers' recommended safety information for the reagents used should be followed.

6.6 Preparation of Standards

All stock standards are uniquely identified and labeled with the standard's name and concentration, date of opening, and analyst's initials.

All stock standards should be purchased in a methanol solution and be manufacturer certified and traceable. Stock solutions are stored at 4°C and must be replaced after 6 months or sooner if comparison to check standards indicates a problem. Stock standards must be purchased from at least two suppliers to obtain a second-source quality control check standard. Stock solutions of 200 parts per million (ppm), 2,000 ppm, and 5,000 ppm are recommended for most projects. The second-source calibration verification

standard stock solution can be at 200 ppm. The calculations required to determine the dilution required for the different standard concentrations are in Appendix B.

6.7 Intermediate Stock Solution

A 100-ppm intermediate stock solution is prepared in purge and trap (or pesticide) methanol containing all target analytes from higher concentration standards using the equation in Appendix B. The stock solutions used, their expiration dates, and details of the preparation of the standard (calculations) shall be documented in the run log notebook.

6.8 Working Calibration Standards

A working standard solution is prepared from the intermediate stock standard solution using the equation in Appendix B such that it contains the desired initial, continuing, or quality control verification concentrations. All working calibration standards are prepared in water. The working stock standard mixtures are project specific and the final concentration may be adjusted according to the project's requirements.

6.9 Initial Calibration Standards

Prepare initial calibration standards in water from the intermediate stock standard solution at a minimum of three concentration levels. Use the equation in Appendix B to determine the dilution volumes required. The lowest standard should be at the reporting limit. The remaining standard concentrations should define the working range of the GC: one at the upper linear range and the other midway between it and the lowest standard. Initial calibration standards must be replaced as each new calibration curve is required.

6.10 Continuing Calibration Standards (CCAL)

The continuing calibration standard (CCAL) is prepared as described for initial calibration standards in Section 6.9, at the initial calibration midpoint level concentration in water. The CCAL must be replaced weekly or sooner if comparison with the initial calibration standard indicates a problem.

6.11 Quality Control Verification Standard

The quality control verification standard or laboratory control standard (LCS) is prepared from an intermediate stock standard as are the initial and continuing calibration standards. The intermediate stock standard must be prepared using an alternate second source (different from the standard solutions used during the preparation of the initial and

continuing calibration standards). The LCS must be replaced weekly, or sooner, if comparison with the CCAL indicates a problem.

6.12 Matrix Spike Solution

To prepare a matrix spike standard solution, an intermediate standard containing the project-specific spike compound or compounds must first be made as described in Section 6.7. From this intermediate stock standard a matrix spike sample can be prepared at 5-10 times the concentration of the low calibration level by spiking the intermediate stock standard directly into the sample. The volume of spike mix required can be calculated using the equation in Appendix B.

6.13 Review Important Points

Before beginning the analysis, the GC Operator should review the following important points and cautions:

- Never remove the carrier gas or adjust the carrier gas during an analytical run. If the gas is adjusted or turned off and on, the GC will have to be recalibrated.

- The stock standards need to be refrigerated while not in use and allowed to come to room temperature before taking an aliquot. These standards should not be used beyond 6 months after the open date or beyond their expiration date. All standards should be labeled with the receipt date, open date, and analyst's initials.

- There should be no smoking, eating, or drinking in the laboratory area of the field trailer during analysis.

- No gasoline-powered equipment should be in the proximity of the sample analysis area.

- There should be no chemicals stored or used near the area of the analysis.

- Care should be taken <u>not</u> to inject liquid into the GC.

- When working with samples in the ppb concentration range, <u>freshly</u> prepared aqueous standards should be used on a daily basis. The

standards should be stored with the septum screw capped and VOA vial inverted.

- Typically, injection volume of headspace ranges between 100 and 500 microliters.

- When using the 10S50 GC, use a separate library for water standard data. By listing the headspace concentration as the liquid concentration, from the standards, the GC will print results based on liquid concentration for field samples. This approach will prevent confusion with air calibration data and negates the need for using Henry's Law to calculate vapor concentration with respect to the liquid samples.

- A change in the instrument gain will void the calibration.

7.0 RESPONSIBILITIES

7.1 Field Operations Leader

The Field Operations Leader is responsible for ensuring that the sampling and analysis plan is carried out. This person also serves as the liaison person between the GC Operator, the sampling crew, and the Project Manager.

7.2 GC Team Leader

It is the responsibility of the GC Team Leader to ensure that this procedure is performed by a chemist or analyst that has been trained properly in its use and limitations. The GC Team Leader must document this training and submit the documentation to the Project QA/QC Officer for inclusion in the training file.

7.3 GC Operator

The field GC Operator or designated alternate will be responsible for ordering all the necessary equipment and supplies required for the project that are not currently in the warehouse inventory. The GC Operator will also be responsible for the setting up and initially checking out of field GC prior to the beginning of the field sampling effort and all subsequent field maintenance that may be required. The GC Team Leader must be consulted before any major instrument maintenance is performed. The operator will also establish the elution order and perform a method detection limit study prior to the field

sampling effort. The GC Operator will also be responsible for receiving, analyzing, and reporting analytical results for the field samples following this SOP. At the end of the project, the GC Operator must complete all instrument logbooks, disassemble the field GC, inventory the supplies, and return the instrument to the warehouse for proper storage. The GC logbooks should be returned to the GC team leader for review and storage.

8.0 PROCEDURES

8.1 Summary

A 20-ml water sample is placed into a 40-ml volatile sample vial with a Teflon® septa seal. The headspace volume is to be consistent for all samples and standards. The containers are sealed and allowed to equilibrate at a temperature near the boiling point of most volatile target analytes in the headspace sampler. A sample is withdrawn from the headspace via an airtight syringe punctured through the septum and injected into a temperature-programmed Photovac 10S50 gas chromatograph equipped with a CPSil 5-capillary column. VOCs are detected with a PID. Quantitation and identification are based on relative peak response and relative retention items using the external standard method.

8.2 Sample Handling, Preservation, and Holding Times

The collection of water samples for organic analysis will follow the protocol specified in the project SAP. For most projects, water samples are collected in replicate 40-ml VOA vials and are collected both with and without preservatives (pH<2 with HCl). The samples are stored at 4°C ± 2°C until analysis. The unpreserved samples are to be analyzed by the headspace method using the Photovac field GC and analyzed as soon as possible. Because of the volatility of the organic compounds, samples should be analyzed within 24 hours. The holding time for the unpreserved samples is technically 7 days. The method suggests that approximately 10% of the samples to be sent to the laboratory for confirmatory analysis by method SW8240 or SW8260. A 14-day holding time applies to the preserved samples that are sent to the laboratory for analysis.

8.3 Instrument Set-Up

The instrument set-up is described in Appendix C of this SOP and is used in conjunction with the manufacturer's instruction manual. Record all pertinent information in the GC logbook including, but not limited to, the following items:

A. Instrument and Detector Identification

B. Lamp Type

C. Column Identification

Record the column type, column packing, coating, length, purchase date, date conditioned, and resolution information (if known).

D. Carrier Gas Used

Record the type of carrier gas used. Remember the carrier gas must be free of contaminants and should be checked periodically as follows:

1. Adjust the Gain to a Setting of 2.

2. Check the offset value, which is printed on the detailed analysis report. Make sure the value reads between 10 and 50 mV. If the value exceeds 50 mV, contamination from the gas should be expected.

E. Gas Flow Rate

Record the gas flow rates that are being used.

F. Gain Setting.

8.4 Elution Order

The GC Operator must establish the elution order for the target analytes prior to the initial calibration. This is accomplished by analyzing the individual target analytes separately and recording their retention times. Chromatography should be optimized to minimize all elution and peak blending (i.e., doublets, triplets). Elution orders can be confirmed via the column manufacturer's supplied specifications. This process confirms the elution order and optimizes the chromatography for the standard mixture that will be used in the calibration process. All instrument libraries should be updated based on the results of the elution order determination.

8.5 Retention Time Windows

The retention time for each of the target analytes is established during the determination of the elution order as described in Section 8.4. The retention time for each target analyte is programmed into the instrument. The GC Operator must now establish the GC window

to be used for each compound. The Photovac allows the operator to choose a window for each compound that is either 2%, 5%, or 10% of the compound's retention time.

The GC Operator must be aware of any shift in retention time windows and take the appropriate corrective action. A reanalysis of the 50-ppb calibration verification standard is used to adjust the retention times when a shift has occurred.

8.6 Calibration

A. Initial Calibration

Using the three calibration standards prepared according to Section 6.9, generate an initial calibration curve (relative response [volt-second] versus concentration of standard injected for each target analyte).

1. A 100-microliter sample is taken from the headspace above the low calibration standard that has been heated to 65°C for 15 minutes shaken violently for 1 minute, and injected into the GC. The analysis is repeated for the remaining two standards. After the three calibration standards have been analyzed, the linear regression is calculated for each compound. The calibration curve will be acceptable if the correlation coefficient exceeds 0.995. The correlation coefficient will be calculated from the quantitated value versus the known concentration of the standard. Alternatively, the correlation coefficient of the linear regression can be calculated as the instrument response in volt-seconds versus the known concentration. The equation used to calculate the correlation coefficient is given in Appendix B.

2. The three-point calibration is performed at the beginning of the project and repeated only if the continuing calibration standard (50 ppb CCAL) is not within the QC limits of ± 25% of the original calibration standard.

3. A new calibration curve must be established any time the GC system is altered (e.g., new column, change in gas supply, change in lamp, change in oven temperature) or shut down.

8.7 Continuing Calibration Verification

A. The continuing calibration verification standard is used to verify that the GC system has maintained its calibration since running the initial calibration standards. This single-point analysis follows the same analytical procedures used in the initial calibration. The midrange calibration verification standard is run initially, and at the end of each batch of samples, including the last batch of samples each day. The GC Operator may run this calibration more frequently if it is deemed necessary. Instrument response is used to compute the standard concentration, which is then compared to the last single-point calibration update. The relative percent difference (RPD) for all target analytes must be less than or equal to 25% for the continuing calibration to be considered valid. If the CCAL standard results are not acceptable then the system must be recalibrated.

B. Use the continuing calibration in all sample concentration calculations for the period over which the calibration has been validated. This is done by updating the responses stored in the compound library daily after each CCAL.

8.8 Analysis

A. Sample Handling
The samples to be analyzed are received directly from the field team's courier and are signed for via the chain-of-custody section of the report form (See report form in Appendix D). All samples received are inspected visually and any unusual appearances such as sediments, air bubbles, presence of two phases etc. are recorded on the sample receipt form. The sample bottles are initialed and dated by the analyst and placed in the refrigerator at 4°C until analyzed.

B. Sample Extraction
All samples, standards, and QC samples must have constant final volumes to allow for constant headspace volume. The next two paragraphs describe alternative procedures to ensure equal final volumes of 20 mls of headspace vapor.

1. Clean 40-ml VOA bottles used to contain 20 ml of sample as measured from a 25 ml graduated cylinder. The sample is removed from the refrigerator and the aqueous sample is gently transferred to the 20-ml mark of the graduated cylinder and then gently transferred into a new VOA bottle that has been labeled with the sample number. The samples are to be analyzed as soon as possible.

After the 20 mls of the sample has been transferred to a new VOA bottle, the original VOA bottle is resealed and returned to the refrigerator. This remaining sample serves as a backup sample (should it be needed) and as a duplicate or dilution sample if required, however these follow-up analyses must be done immediately.

OPTIONAL: Immediately add 20 microliters (or the appropriate volume) of surrogate standard to the sample vial with a syringe.

C. The sample VOA bottle is placed in the constant-temperature bath and held at 65°C for 15 minutes.

D. After 15 minutes, the sample vial is removed from the constant-temperature bath and is shaken vigorously 1 minute. A 100-microliter sample of the heated headspace vapor is taken and injected into the GC.

8.9 Gas Chromatographic Analysis

A. Daily Run Log

1. Syringe and instrument blank.
2. Initial calibration (start of project and as required).
3. Continuing calibration verification (50 ppb) standard.
4. Method blank.
5. 10 or fewer samples (blanks run following any high concentrated samples).
6. Check standard solution (second source).
7. Repeat sequence beginning with step 5 until all sample analysis are completed.
8. MS/MSD and duplicate samples are required at least one per day.
9. Final calibration by reanalyzing the CCAL when all samples analyses are completed.
10. Examine samples under the same parameters as the calibration standards. Dilute and reanalyze those samples with responses that exceed the demonstrated working range of the calibration curve.
11. Qualitative identification of VOCs is based on relative retention time as compared to known standards using the

external standard method. Peak response should be greater than baseline noise levels and less than 100% of full-scale deflection.

8.10 Integration

Each analyte is integrated as an individual peak via the internal processor of the instrument. Consistency of the way the baseline is interpreted and drawn by the instrument should be monitored by the analyst. All unusual or suspect baselines should be noted by the analyst and possible duplicate sample injections should be run at the analyst's discretion.

8.11 Calculations

The Photovac GC should be programmed to perform the necessary calculations to determine a sample's concentration. Appendix B contains all the equations necessary to perform these calculations using a calculator should it become necessary to verify the Photovac's internal processor's calculation.

The Photovac GC is programmed to print the sample's concentration directly on the chromatograph print out at the end of each run.

8.12 Reporting Results

Results are reported in ppb (µg/L) without correction for blank or spike recovery.

8.13 Data Review

The GC Operator should meet with the Field Operations Leader and review the analytical results obtained. The field GC Operator may recommend that certain samples be sent to the laboratory for confirmatory analysis by method SW8240 or SW8260. The following information must be recorded for each chromatogram in the GC project logbook. The following items marked with an "*" should be recorded directly on the chromatograph:

- Instrument and detector identification;
- Column packing, coating, length, and I.D.;
- Oven temperature;

- Gas and flow rates;
- Site name;
- Sample number*;
- Number of microliters of sample injected*;
- Dilution factor*;
- Date and Time*; and
- GC Operator's initials*.

At a minimum, the sample number, date, and GC Operator initials must be on the chromatograph. The chromatographs will be attached in the project notebook in the order of analysis as given by the analysis run log.

8.14 Quality Control

A number of quality control procedures will be followed to ensure that valid data are obtained during the sampling event.

A. Instrument Blank
This blank is the type used to initially zero the instrument. It consists of using the carrier gas as a sample.

B. Method Blank
This blank is the type used to check the vials and laboratory water for contamination. It is the type run following any calibrations.

C. Duplicate Sample
A duplicate sample should be run after every 10 field samples (10% of the samples). In general, duplicate analyses of the same sample should have an RPD less than 30% to be regarded as within the necessary analytical precision.

D. Other Blanks
Equipment blanks and syringe blanks should be analyzed as required by the project.

E. Matrix Spike/Matrix Spike Duplicates

Matrix spike (MS) analysis will be performed to assess accuracy. One matrix spike and matrix spike duplicate (MSD) for every 20 samples should be analyzed. Quality control criteria must be met for all analytes. The advisory limit for spike recoveries is 50-150% for all compounds in Table 1. The duplicate spike %RPD is ± 30. Percent recovery of the surrogate may not be used in place of the matrix spike.

F. Summary of Quality Control Measures

A summary table showing the quality control measures of the field GC screening of water samples is given in Appendix E.

8.15 Troubleshooting

A troubleshooting guide for the Photovac GC can be found on pages 82-85 of the Photovac instrument manual. Some of the more common problems such as poor peak resolution, poor replication, and poor standard recoveries are discussed in Appendix F.

8.16 Equipment Maintenance

Spare parts for the GC will either be maintained on site or will be readily available from the manufacturer to minimize equipment down time.

A. Column Conditioning Procedure

Maintain a continuous flow of clean carrier gas through the column, even when it is not in use. If the column appears to be contaminated as indicated by a high background reading, the column must be baked out or possibly reconditioned. Reconditioning consists of placing the column (with an inert gas such as nitrogen or helium flowing through it) into an oven at 100°C for 8 hours. If conditioning fails to remedy the problem, the column must be replaced.

B. UV Source Check Results

Check that the source power value lies between 20 and 50 units. If the power source is outside of this range, go to the troubleshooting section of the instrument manual.

Upon initial power-up, a lamp not ready message should appear. After 3 minutes a READY ENTER COMMAND should appear if the lamp is lit. A slight smell of ozone should be apparent at the "DETECTOR OUT" port, if the lamp is working properly.

8.17 Records Management/Documentation

A. GC Logbook
The GC logbook for the Photovac shall be kept current by the analyst.

B. Project Logbook
The project logbook shall be kept current by the analyst. This logbook shall also contain the preparation and runlogs for the project as well as all the relevant instrument information.

C. Project Notebook for Data Strips from Photovac
The analyst shall attach each chromatograph into this notebook and record any relevant details for each sample.

D. Project Report Forms
The report form in Appendix D will be used for reporting the field GC results. The completed form will be given to the Field Team Leader at the completion of each analysis or at the end of the day depending on the project's time requirements.

8.18 Nonconformance and Corrective Action

The GC Team Leader shall review the work of the GC Operator. This will consist of a review of the data and an actual field audit if deemed necessary. All nonconformances will be documented along with the recommended corrective action to be instituted.

9.0 APPENDICES

Appendix A Training

Appendix B Calculations

Appendix C Photovac Set-Up Instructions

Appendix D Form 1 for Lowry Air Force Base Project

Appendix E QA/QC Summary Table

Appendix F Troubleshooting

APPENDIX A

TRAINING

Field GC Operators need to be trained adequately prior to using the onsite GC. Topics covered in this training need to include, but are not limited to, the following:

1) Fundamental principles of gas chromatography;
2) Data interpretation, use and limitations;
3) Quality assurance practices and quality control requirements; and
4) Instrument set-up, troubleshooting, and maintenance.

APPENDIX B

CALCULATIONS

1. Calculations for Standard Preparation

All standards can be calculated via the following equation of concentration versus volume:

$(C_1)(V_1) = (C_2)(V_2)$

C_1 = Concentration of stock standard in ppm.

C_2 = Desired concentration of new standard in ppm.

V_1 = Volume in µL of C_1 required to make C_2

V_2 = Final volume of new standard required in µL.

Solve the equation for the unknown variable V_1.

This is the volume in µl of the stock solution that is to be diluted to the final volume, V_2.

2. Initial Calibration

Analyze each calibration standard. Tabulate the volt-second of each target analyte against concentration for each compound and calculate the calibration factors (CFs) for target compound using the following equation:

$$CF = \frac{\text{Area of Peak}}{\text{Mass Injected (nanograms)}} = \frac{\text{Area of Peak (volt-second)}}{\text{concentration of standard}}$$

Using the calibration factors, calculate the relative standard deviation (RSD) for each target analyte at all concentration levels using the following equation:

$$RSD = SD/X \times 100$$

where SD, the standard deviation is given by

where: X_i = Individual CF (per analyte)

X = Mean of initial CFs (per analyte)

N = Number of calibration standards.

3. The %RSD Must be Less than or Equal to 25%.

4. Continuing Calibration

Sample quantitation is based on analyte CFs calculated from continuing calibrations. Whenever the midrange CCAL is analyzed, the RPD must be <25%. The RPD is calculated using the following equation.

where: CF_I = Mean CF from the initial calibration for each analyte
CF_C = Measured CF from the continuing calibration for the same analyte.

5. Sample Calculation

External standard calibration is used for the calculation of the compounds of interest. The concentration of each calibrated analyte may be determined by the following formula:

$$\text{Concentration } (\mu g/L) = \frac{(Ax)}{(V)(CFc)}$$

where: A_x = Area (or volt-second) of the peak for the analyte to be measured

V = Volume (mL) of sample in vial
CF_C = Calibration factor for the analyte to be measured.

The Photovac GC can be programmed to print the sample's concentration directly on the chromatograph print out at the end of each run.

APPENDIX C

PHOTOVAC SET-UP INSTRUCTIONS

1. Open Photovac 10S50 instrument casing.
2. Connect instrument to 110V outlet using supplied cord.
3. Connect 12V power supply to EXT DC Port.
4. Set Column Temp. select switch to 30°C (green lights should indicate 30° setting selected).
5. Press "ON" button. After approximately 3 minutes "READY ENTER COMMAND" should appear on screen.
6. Connect air supply to "EXTERNAL CARRIER IN" port.

   Air supply should be ULTRA ZERO Grade Air.

   Regulator should be set to deliver 40 psi to instrument.
7. Connect air flow meters to "DETECTOR OUT" port and "AUX OUT" port.
8. Adjust flow so that both ports receive 16 mils/min using the red "B" valve and the "AUX OUT" valve. (16 mils/min on present flow meters requires a "30" reading on each meter).
9. Press "USE" button.
10. Press the number "1" button.
11. Press "ENTER". The library is now set to 1.
12. Press "GAIN". Using the up & down arrow keys, select 10 and press "ENTER".
13. Press the "CHART" button. Use the up & down arrow keys to select "ON WITH BASELINE" and press "ENTER". Chart speed will then be displayed. Use the up & down arrow keys to select 1 cm/in. Press "ENTER".
14. Press the "WINDOW" key. Use the up & down arrow keys to select 10%. Press "ENTER".
15. Press "CYCLE", "Timer Delay" will be displayed. Press the "0" key and press "ENTER". "Analysis Time" will then be asked. Enter analysis run time (325) and press "ENTER".
16. Press the "EVENT" key. Press 1 and "ENTER".

    "ON AT?" will be displayed. Press "0" and "ENTER".

    "OFF AT?" will be displayed. Press "0" and "ENTER"
17. Press "EVENT" again. Press "2" and "ENTER".

    "ON AT?" will be displayed. Press "0" and "ENTER".

"OFF AT?" will be displayed. Press "0" and "ENTER"

18. Press "EVENT" again. Press "3" and "ENTER".

    "ON AT?" will be displayed. Press "10" and "ENTER".

    "OFF AT?" will be displayed. Press "100" and "ENTER"

19. Go to Step 17 and enter Events 4 through 8 as if they were event 2.

20. Press "START/STOP" key and then press "ENTER". Instrument will begin and start the analysis. After 8 seconds, a buzzing sound will occur for 2 seconds (Event 1). After buzzing stops (10 seconds), ensure "AUX OUT" flow drops to zero. Ensure "DETECTOR OUT" flow remains at "30" (use red valve to adjust).

21. After 100 seconds (Event 3), the flow from "AUX OUT" should remain at "30" and the "DETECTOR OUT" flow should remain at "30". Adjust the "AUX OUT" valve and the red "B" valve to ensure flow remains as specified throughout the analysis run.

22. Press the "START/STOP" key and "ENTER".

23. When buzzing sound ceases, inject standard into "Manual Injection" port number 1.

24. After analysis run time ends, the printer will label chromatogram with Library #, Stop time, Analysis #, Temp, Date, Time, Gain, and a list of peaks present in chromatogram.

25. Press the "STORE" key. Instrument will ask "Plotter Peak #?".

    Press the number of the peak you want to calibrate and press "ENTER". Instrument will respond with compound name.

    Enter compound name and press "ENTER". Instrument responds "CONC?".

    Enter compound concentration and ppm and press "ENTER". Instrument responds with "Limit Value?".

    Press "0" and "ENTER".

    Continue as above for all compounds to be calibrated.

    Instrument is now calibrated and ready for use.

26. Press "START/STOP" key and "ENTER". When the buzzing sounds ceases, inject sample into Port 1 as above.

CALIBRATE REFRESH - DAILY (Retention time and conc.)

1. Inject standards as before and wait for run to end.
2. Press "CAL" key. Instrument will ask for "Plotter Peak?".

Enter peak numbers. Instrument will ask for Library "I.D. Number?" (The number by which the compound is listed in the Library).

Enter I.D. Number and press "ENTER". Instrument asks for concentration of compound: "CONC in PPM".

Enter compound concentration and press "ENTER". The calibration is now updated.

SEPTA CHANGE - DAILY

1. Insert syringe into Port 1 but do not remove.
2. Unscrew Port 1 (Counter clockwise).
3. Remove Port and pull old septa from needle.
4. Place new septa into instrument.
5. Remove syringe from Port 1 and screw Port back onto septa. Instrument is now ready for use.

APPENDIX D

FORM 1 FOR REPORTING DATA RESULTS

APPENDIX E

QA/QC SUMMARY TABLE

SUMMARY OF QUALITY CONTROL MEASURES FOR FIELD GC SCREENING OF WATER SAMPLES BY HEADSPACE GAS CHROMATOGRAPHY FOR THE LOWRY AIR FORCE BASE SRI/FS PROJECT

QA/QC Sample	Frequency	Action if Out of Control
Initial CCAL	1 per Day	Calibrate Instrument
MS/MSD	1 in 20	Associated Data are Flagged
CCAL	1 in 10	Instrument is Recalibrated
Instrument Blanks/and Method Blanks	1 per Day	Data are flagged <2 times Blank Level
3-Point Calibration	At project start and as Needed	Correlation Coefficient Must be ≥0.995
Duplicates	1 in 10	Calibration is checked, Run CCAL

APPENDIX F

TROUBLESHOOTING

1. Poor Replication

A leaky plunger in your syringe can cause poor replication of standards and samples. If the plunger is not tight and flush with the barrel, the back pressure created during the injection can blow the sample backward around the plunger. The sample will be lost or partially lost and your peaks will not come out the same each time.

Another factor which can affect replication is the state of the septum itself. This silicone rubber component can normally be expected to last for at least 50 injections before it requires replacement; with certain needle-type styles, this number may increase. If, however, the septum has been penetrated so many times that is has begun to leak, you can expect to lose sample on injection and thus also lose replication. If the septum is suspect, replace it with a new one.

2. Poor or No Standard Recovery

Standard recovery can be affected by the age of the standard being used or the duration of time since opening the vial. If the standards are not giving comparable peak areas to past standards, choose a fresh standard for analysis and recalibrate.

The GC septum can be affected by the septum retainer (black O-ring around edge of the septum) if it is too tight. The septum becomes highly compressed if the O-ring is tightened down to the point of causing one to feel resistance as the needle is being pushed down. In this case the syringe needle often becomes blocked with a core of the septum material. As a result no or very little standard will be injected into the GC. A fine cleaning wire will be needed to clean the plug from the syringe needle.

The GC septum can leak if the O-ring is not tightened enough and this will also result in poor recovery.

If a standard is not allowed to equilibrate with the headspace above it, a poor standard recovery will result. Allow all samples to equilibrate the same amount of time and to the same temperature. For this project 15 minutes and 65°C.

The precision is also affected by the analyst's injection technique. The injections should be made in a reproducible manner using a quick, fluid motion.

3. Poor Resolution of Peaks

Poor peak resolution can be caused by an oven temperature which has been set too high. Decreasing the oven temperature will provide better peak resolution. The temperature should be set to provide the required resolution while minimizing the run time. The best range for the 10S50 is between 30° and 40° C. The room temperature should be maintained as constant as possible and preferably below the temperature of the column.

4. Other Problems

The Photovac instrument manual on pages 82-85 provides additional trouble shooting guides for other problems that might be encountered.

5. Interferences

Samples can be contaminated by diffusion of volatile organics through the sample container septum during shipment and storage. Analysis of a trip blank serves as a check on such contamination.

Laboratory air can be a source of contamination problems. The laboratory should be as completely free of interfering solvents as possible. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent or system blanks.

The injection syringes may be a source of contamination. Contamination by carry-over must be avoided whenever high-level samples are analyzed. A syringe blank is run following the standards and high-level samples to ensure that the injection syringes are not adding contamination to the system.

Methanol contamination from the syringes used to make up the standard solutions may occur if these syringes are used to inject samples into the GC. To avoid methanol contamination (Methanol will cause problems for the column resulting in irregular baselines.) separate syringes are used for standard preparation and for sample injections.

Compounds of unknown origin may be detected by the PID detector. Compounds that have not been included in the standard mixture will not be quantitated. These compounds will be reported as unknowns. The GC Operator will discuss these results with the Field Team Leader, and if necessary, send the samples to the laboratory for a complete analysis of the unknown compounds.

APPENDIX B

ADDENDUM TO THE PROGRAM HEALTH AND SAFETY PLAN FOR RISK-BASED REMEDIATION DEMONSTRATIONS

ADDENDUM TO THE PROGRAM HEALTH AND SAFETY PLAN
FOR
RISK-BASED REMEDIATION DEMONSTRATIONS

AT
LANDFILL B

WESTOVER AIR RESERVE BASE
CHICOPEE, MASSACHUSETTS

JANUARY 1997

Prepared by

PARSONS ENGINEERING SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290

Reviewed and Approved By:

	Name	Date
Project Manager	Doug Downey	1/2/97
Office Health and Safety Representative	Timothy J Mustard, CIH	1/2/97

022/730486/WP/10.DOC

B.1.0 INTRODUCTION

This addendum modifies the existing program health and safety plan entitled *Health and Safety Plan for Risked-Based Remediation Demonstrations* (Engineering Science, Inc., 1994) for the evaluation of the risk-based approach to remediation to reduce contaminant concentrations of fuel hydrocarbons and chlorinated solvents in the groundwater at Air Force installations across the United States.

Under contract number F41624-93-C-8044, Mod 8, Air Force Center for Environmental Excellence (AFCEE), Brooks Air Force Base, Parsons Engineering Science, Inc. (Parsons ES) was requested to conduct site investigations to assist the Air Force in developing and implementing a practical, risk-based approach to fuel hydrocarbon remediation.

This addendum to the program health and safety plan was prepared to address the upcoming tasks at Westover Air Reserve Base (ARB) in Chicopee, Massachusetts. Included or referenced in this addendum are the scope of services, site specific description and history, project team organization, hazard evaluation of physical hazards and of known or suspected chemicals, emergency response information, levels of protection and personal protective equipment, and frequency and types of air monitoring. All other applicable portions of the program health and safety plan remain in effect.

B.2.0 SCOPE OF SERVICES

The scope of services to be completed by Parsons ES at Westover ARB will require the collection of site data required to demonstrate that an alternative closure approach, including a modified cover system design, will provide an "equivalent" level of protection to surface water and groundwater resources when compared to a standard closure approach as set forth in the Code of Massachusetts Regulations.

Activities to be performed include use of the Geoprobe® direct-push technology for soil sampling and monitoring point installation, the use of a slide hammer for soil and soil gas sampling, groundwater sampling from existing monitoring wells and the newly installed monitoring points, and surface water sampling.

B.3.0 SITE SPECIFIC DESCRIPTION HISTORY

The site description, history, and maps for Landfill B are contained in the work plan portion of this document and is entitled *Work Plan for a Phase III RAP/Phase IV RIP to Support the Risk-Based Approach to Remediation, Landfill B, Westover Air Reserve Base, Massachusetts* (Parsons Engineering Science, Inc., 1997).

Landfill B consists of approximately 14 acres in the northwest corner of the base. The landfill was a disposal area for domestic and general base refuse and operated from 1960 to 1974. The refuse included 55-gallon drums and empty containers used in base industrial operations. Additional waste may have included leaded fuel filters and leaded sludge from fuel tanks, paint residues, thinners, strippers, and aircraft cleaning compounds. At the conclusion of disposal activities, a silty, fine sand cover with a

maximum thickness of two feet was placed over the landfill. Currently, the landfill is partially forested.

B.4.0 PROJECT TEAM ORGANIZATION

The project team assigned to the risk-based demonstration activities at Westover ARB are identified in the program health and safety plan. The following personnel will also be involved in this project.

Ms. Leigh Benson	Technical Director
Mr. Doug Downey	Project Manager
Mr. Mark Vessely	Site Manager
Mr. Craig Snyder	Site Health and Safety Officer
Mr. Greg Knight	Alternate Site Health and Safety Officer
Mr. Patrick Haas	AFCEE/ERT Point of Contact

B.5.0 HAZARD EVALUATION

B.5.1 Chemical Hazards

The contaminants of concern at Landfill B are chlorinated solvents; metals; pesticides; the semivolatile, bis (2-ethylhexyl) phthalate; methane; and the petroleum hydrocarbon components benzene, toluene, ethylbenzene, and xylenes (BTEX). Health hazard qualities for these compounds are presented in Table 5.1 at the end of this addendum. If other contaminants are found to exist at the site, this addendum will be modified to include the necessary information which will then be communicated to the onsite personnel.

B.5.2 Physical Hazards

Potential physical hazards at Westover ARB include hazards associated with the slide hammer and the Geoprobe® unit; motor vehicles; subsurface and partially buried debris; slip, trip, and fall hazards; noise; and cold exposure. These hazards are discussed in the program health and safety plan.

B.6.0 EMERGENCY RESPONSE PLAN

B.6.1 Emergency Contacts

In the event of any emergency, situation or unplanned occurrence requiring assistance, the appropriate contacts should be made form the list below. <u>A list of emergency contacts must be posted at the site.</u>

Contingency Contacts	Telephone Number
Westover ARB Fire Department	(413) 557-1117
Chicopee Fire Department	(413) 594-6631
Westover ARB Security	(413) 557-2080
Chicopee Police	911 or (413) 592-6341

Poison Control Center	(800) 682-9211
Site Contacts:	
Paul Kwiatkowski or	(413) 557-2541
Jack Moriarty	(413) 557-2434

Medical Emergency (on-base facilities)

Base Clinic	Medical Training Facility
Hours	0730-1630 (after business hours, call the Westover Fire Dept.)
Address	Building 2235 Walker Avenue Westover ARB, Massachusetts
Telephone Number	(413) 557-3196
Ambulance (call Westover Fire Dept.)	(413) 557-1117

Directions to the Base Clinic:

From Landfill B, proceed to Patriot Road and turn left. Continue along Patriot Road to Airlift Drive. Turn right onto Airlift Drive and proceed 3 blocks to Walker Avenue. Turn right onto Walker Avenue. The clinic is on the left side of the street.

Medical Emergency (off-base facilities)

Hospital	Community Medical Center
Address	268 North Ludlow Road Chicopee, Massachusetts
Telephone Number	(413) 533-3926

Directions to Hospital:

From Landfill B, turn left onto Patriot Road and then turn right onto Eagle Drive. At Central Avenue, turn right and proceed to the main security gate on First Street and exit the Base. Continue straight onto Ludlow Road. Follow Ludlow Road to approximately the intersection with Bernice Street where the hospital is located.

Parsons ES Contacts	Telephone Number
Doug Downey Project Manager	(303) 831-8100 (Work) (303) 670-0512 (Home)
Tim Mustard, CIH Program Health and Safety Manager	(303) 831-8100 (Work) (303) 450-9778 (Home)

Ed Grunwald, CIH Corporate Health and Safety Manager	(404) 235-2300 (Work) (404) 299-9970 (Home)
Judy Blakemore Assistant Program Health and Safety Manager	(303) 831-8100 (Work) (303) 828-4028 (Home) (303) 817-9743 (Mobile)

B.7.0 LEVELS OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT REQUIRED FOR SITE ACTIVITIES

The personal protection level prescribed for field activities at Westover ARB is OSHA Level D with a contingency for the use of OSHA Level C or B as site conditions require. The flow chart presented in Figure 7.1 of this addendum and discussed in the program health and safety plan will be used to select respiratory protection with the following comments and additions.

A reading of 1 part per million (ppm) above background in the worker breathing zone as indicated by a photoionization detector (PID) will require the use of a Dräger® tube or the equivalent to determine if vinyl chloride is present at a concentration greater than or equal to the permissible exposure limit (PEL) of 1 ppm. Due to the inadequate warning properties of vinyl chloride, Level B protection must be used if concentrations of vinyl chloride exceed 1 ppm above background in the worker breathing zone.

If vinyl chloride is not present, the flow chart presented in Figure 7.1 of this health and safety addendum will be followed. Periodic testing of vapor concentrations for the presence of vinyl chloride will be performed if concentrations persist above 1 ppm above background in the worker breathing zone, as indicated by the PID.

Based on previous investigations in the areas under investigation, the low concentrations of metals, semi-volatiles and other chemicals are not expected to pose an inhalation hazard to field personnel. In addition, Geoprobe® operations typically do not create dust problems. The partial vegetative cover combined with safe work practices will assist in preventing dust from becoming a hazard.

Additional personal protective equipment will be selected as stated in Section 7.1 of the program health and safety plan.

B.8.0 FREQUENCY AND TYPES OF AIR MONITORING

A PID with an 11.7 electron volts (eV) (HNU®) or equivalent lamp will be used for air monitoring during this project since the ionization potentials of the contaminants of concern are less than 11.7 eV.

An explosimeter must also be used during this project, since the PID is unable to detect methane. Monitoring with the explosimeter will be performed at the ground surface and in the worker breathing zone. Personnel will evacuate the area if breathing zone readings are 10 percent of the lower explosive limit (LEL), as stated in the program health and safety plan.

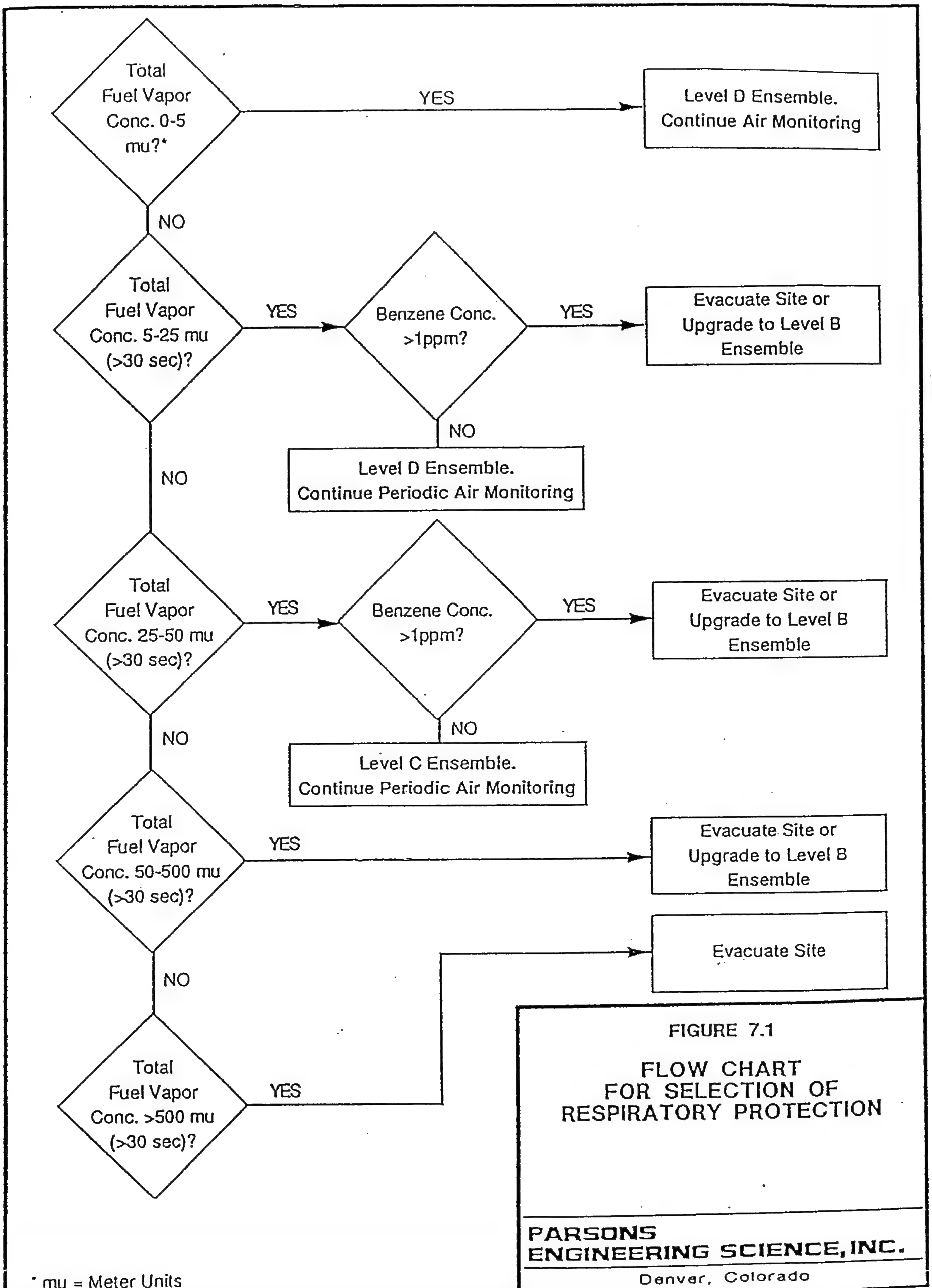

FIGURE 7.1

FLOW CHART FOR SELECTION OF RESPIRATORY PROTECTION

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a/] (ppm)	TLV [b/] (ppm)	IDLH [c/] (ppm)	Odor Threshold [d/] (ppm)	Ionization Potential [e/] (eV)	Physical Description/Health Effects/Symptoms
Benzene	1 (29 CFR 1910.1028) [f/]	10	500	4.7	9.24	Colorless to light-yellow liquid (solid<42oF) with an aromatic odor. Eye, nose, skin, and respiratory system irritant. Causes giddiness, headaches, nausea, staggered gait, fatigue, anorexia, exhaustion, dermatitis, bone marrow depression, and leukemia. Mutagen, experimental teratogen, and carcinogen.
Cadmium (dust)	0.005 mg/m^3 [g,h/] (29 CFR 1910.1027) [f/]	0.01 mg/m^3 [i/] 0.002 mg/m^3 [j/]	9 mg/m^3	NA [k/]	NA	Silver-white, blue-tinged, lustrous, odorless, metallic solid. Causes pulmonary edema, shortness of breath, coughing, chest tightness/pain, loss of sense of smell, chills, muscle aches, headaches, nausea, vomiting, diarrhea, mild anemia, and prostatic and lung cancer. Also attacks kidneys. Mutagen, experimental teratogen, and carcinogen.
Chloroethane (Ethyl Chloride)	1,000	1,000	3,800	NA	10.97	Colorless gas or liquid (<54°F) with a pungent, ether-like odor and burning taste. Irritates eyes, skin, and mucous membranes. Causes incoordination, drunkenness, stomach cramps, cardiac arrhythmia, cardiac arrest, and liver and kidney damage.
Chloroform (Trichloromethane)	2	10	500	205 [l/]	11.42	Colorless, heavy liquid with pleasant odor. Irritates eyes and skin. Anaesthetic. Causes dizziness, mental dullness, nausea, confusion, headache, fatigue, anesthesia, and enlarged liver. Also attacks kidneys and heart. In animals, causes liver and kidney cancer. Mutagen, experimental teratogen, and carcinogen.
Copper (dust/mists)	1 mg/m^3	1 mg/m^3	100 mg/m^3	NA	NA	Reddish, lustrous, malleable, and odorless, solid metal. Irritates eyes, nose, skin, and pharynx. Causes a metallic taste, nasal perforation, nausea, vomiting, and dermatitis. In animals, causes anemia and lung, liver, and kidney damage. Experimental teratogen and questionable carcinogen.

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TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a] (ppm)	TLV [b] (ppm)	IDLH [c] (ppm)	Odor Threshold [d] (ppm)	Ionization Potential [e] (eV)	Physical Description/Health Effects/Symptoms
4,4'-DDE (Dichlorodiphenyl Dichloroethylene)	NA	NA	NA	NA	NA	White, crystalline, solid, organochlorine pesticide. Toxic through all routes of exposure. Irritates skin, eyes, nose, and throat. Affects kidneys, liver, and central nervous system. Mutagen and carcinogen. Use Level B protection.
4,4'-DDT (Dichlorodiphenyl Trichloroethane)	1 mg/m^3 (skin)[m]	1 mg/m^3	500 mg/m^3	2.9 mg/m^3	NA	Colorless crystals or off-white, powdered, organochlorine pesticide, odor- less or with a slight aromatic odor. Irritates eyes and skin. Causes tingling of tongue, lips, face, and hands; tremors; apprehension; dizziness; con- fusion; vague discomfort; headache; fatigue; vomiting; convulsions; and partial paralysis of the hands. Also affects kidneys and liver. In animals causes liver, lymphatic, and lung tumors. Mutagen, teratogen, and carcinogen. Use Level B protection.
1,4-Dichlorobenzene (p-DCB)	75	10	150	15-30	8.98	Colorless or white, crystalline, solid insecticide with mothball-like odor. Irritates eyes, skin, and respiratory tract. Causes eye swelling, profuse runny nose, headaches, anorexia, nausea, vomiting, low-weight, jaundice, and cirrhosis. In animals, causes liver and kidney cancer. Mutagen, experimental teratogen, and carcinogen.
1,1-Dichloroethane (DCA)	100	100	3,000	120	11.06	Colorless, oily liquid with chloroform-like odor and hot saccharine taste. Irritates skin. Causes CNS depression and kidney, lung, and liver damage. Experimental teratogen and questionable carcinogen.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a/] (ppm)	TLV [b/] (ppm)	IDLH [c/] (ppm)	Odor Threshold [d/] (ppm)	Ionization Potential [e/] (eV)	Physical Description/Health Effects/Symptoms
Dieldrin	0.25 mg/m^3 (skin)	0.25 mg/m^3 (skin)	50 mg/m^3	0.04	NA	Colorless to light-tan, crystalline, organochlorine insecticide with a mild, chemical odor. Causes headaches, dizziness, nausea, vomiting, vague discomfort, sweating, limb jerking, convulsions, and coma. In animals, causes kidney and liver damage and lung, liver, thyroid, and adrenal gland tumors. Mutagen, experimental teratogen, and carcinogen.
Ethylbenzene	100	100	800	0.25-200	8.76	Colorless liquid with an aromatic odor. Irritates eyes, skin, and mucous membranes. Causes dermatitis, headaches, narcosis, and coma. Mutagen and experimental teratogen.
Bis(2-Ethylhexyl)Phthalate (Di-sec Octyl Phthalate)	5 mg/m^3	5 mg/m^3	5,000 mg/m^3	NA	NA	Colorless to light-colored, oily liquid with slight odor. Irritates eyes and mucous membranes. Also affects respiratory system, CNS, and gastrointestinal tract. In animals, causes liver damage, liver tumors, and teratogenic effects. Carcinogen.
Iron Salts (soluble, as Fe)	1 mg/m^3	1 mg/m^3	NA	NA	NA	Characteristics vary with compound. Irritates eyes, skin, and mucous membranes. Causes abdominal pain, diarrhea, vomiting, and possible liver damage. In general, ferrous (Iron II) compounds are more toxic than ferric (Iron III) compounds. Some iron compounds are suspected carcinogens.
Lead	0.05 mg/m^3 (29 CFR 1910.1025) [f/]	0.15 mg/m^3	100 mg/m^3	NA	NA	Heavy, ductile, bluish-gray, soft metal. Irritates eyes. Causes weakness, exhaustion, insomnia, facial pallor, anorexia, low-weight, malnutrition, constipation, abdominal pain, gastritis, colic, constipation, gingival lead line, anemia, wrist and ankle paralysis, joint pains, tremors, low blood pressure, and kidney disease. Mutagen, experimental teratogen, and suspected carcinogen.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a] (ppm)	TLV [b] (ppm)	IDLH [c] (ppm)	Odor Threshold [d] (ppm)	Ionization Potential [e] (eV)	Physical Description/Health Effects/Symptoms
Manganese (compounds and fume, as Mn)	5 mg/m^3 (ceiling) [n] 1 mg/m^3 [o]	5 mg/m^3 [p] 1 mg/m^3 [o]	500 mg/m^3	NA	NA	Lustrous, brittle, silvery, solid metal. Irritates eyes and skin. Causes Parkinson's disease, loss of strength, insomnia, confusion, dry throat, coughing, rales, shortness of breath, tight chest, flu-like fever, lower back paint, vomiting, vague discomfort, fatigue, and kidney damage. Fumes cause metal fume fever. Mutagen, experimental teratogen, and questionable carcinogen.
Methane	NA	NA	NA	NA	NA	Colorless, odorless, tasteless gas. Simple asphyxiant, which dimin- ishes the amount of oxygen in the air that is breathed. Causes rapid respiration, air hunger, diminished mental alertness, impaired muscular coordination, faulty judgement, depressed sensations, emotional instability, fatigue, nausea, vomiting, collapse, uncon- sciousness, convulsions, deep coma, and death. Dangerous fire and explosion hazard when exposed to hear or flame.
Methylene Chloride (Dichloromethane, Methylene Dichloride)	500 (proposed 25 ppm)	50	2,300	25-320	11.32	Colorless liquid (gas > 104°F) with a sweet, chloroform-like odor (not noticeable at dangerous concentrations). Irritates eyes and skin. Causes nausea, vomiting, fatigue, weakness, unnatural drowsiness, light- headedness, numbness, tingling limbs, and nausea. In animals, causes lung, liver, salivary and mammary gland tumors. Mutagen, experimental teratogen, and carcinogen.
Perchlorethylene (Tetrachloroethene or PCE)	25 [q]	25	150	5-50	9.32	Colorless liquid with a mild chloroform odor. Eye, nose, skin and throat irritant. Causes nausea, flushed face and neck, vertigo, dizziness, headaches, hallucinations, incoordination, drowsiness, coma, pulmonary changes, and skin redness. Cumulative liver, kidney, and CNS damage. In animals, causes liver tumors. Mutagen, experimental teratogen, and carcinogen.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a] (ppm)	TLV [b] (ppm)	IDLH [c] (ppm)	Odor Threshold [d] (ppm)	Ionization Potential [e] (eV)	Physical Description/Health Effects/Symptoms
Toluene	100	50 (skin)	500	0.2-40 [l]	8.82	Colorless liquid with sweet, pungent, benzene-like odor. Irritates eyes and nose. Causes fatigue, weakness, dizziness, headaches, hallucinations or distorted perceptions, confusion, euphoria, dilated pupils, nervousness, tearing, muscle fatigue, insomnia, skin tingling, dermatitis, bone marrow changes, and liver and kidney damage. Mutagen and experimental teratogen.
1,1,1-Trichloroethane (TCA) (Methyl Chloroform)	350	350	700	20-500	11.00	Colorless liquid with a mild chloroform-like odor. Irritates eyes and skin. Causes headaches, exhaustion, CNS depression, poor equilibrium, dermatitis, liver damage, cardiac arrhythmia, hallucinations or distorted perceptions, motor activity changes, aggression, diarrhea, and nausea or vomiting. Mutagen, experimental teratogen, and questionable carcinogen.
Vinyl Chloride	1 (29 CFR 1910.1017) [f]	5	NA	260	9.99	Colorless gas (liquid <7°F) with a pleasant odor at high concentrations. Severe irritant to skin, eyes, and mucous membranes. Causes weakness, abdominal pain, gastrointestinal bleeding, enlarged liver, pallor or blue skin on the extremities, liver cancer, and frostbite (liquid). Also attacks lymphatic system. Mutagen, experimental teratogen, and carcinogen.
Xylene (o-, m-, and p-isomers)	100	100	900	0.05-200 [l]	8.56 8.44 (p)	Colorless liquid with aromatic odor. P-isomer is a solid <56°F. Irritates eyes, skin, nose, and throat. Causes dizziness, drowsiness, staggered gait, incoordination, irritability, excitement, corneal irregularities, conjunctivitis, dermatitis, anorexia, nausea, vomiting, abdominal pain, and olfactory and pulmonary changes. Also targets blood, liver, and kidneys. Mutagen and experimental teratogen.

TABLE 5.1 HEALTH HAZARD QUALITIES OF HAZARDOUS SUBSTANCES OF CONCERN

Compound	PEL [a] (ppm)	TLV [b] (ppm)	IDLH [c] (ppm)	Odor Threshold [d] (ppm)	Ionization Potential [e] (eV)	Physical Description/Health Effects/Symptoms
Zinc (based on zinc oxide)	5 mg/m^3 [o] 5 mg/m^3 [j] 10 mg/m^3 [r]	5 mg/m^3 [o] 10 mg/m^3 [r]	500 mg/m^3	NA	NA	Fine, white or yellowish, odorless particulate. Irritates respiratory system. Causes metallic taste, cough, chills, fever, tight chest, headaches, rales, blurred vision, muscle aches, nausea, vomiting, dry throat, weakness, lower back pain, exhaustion, fatigue, vague discomfort, shortness of breath, and decreased pulmonary function. Fumes cause metal fume fever. Mutagen and experimental teratogen.

a/ PEL = Permissible Exposure Limit. OSHA-enforced average air concentration to which a worker may be exposed for an 8-hour workday without harm. Expressed as parts per million (ppm) unless noted otherwise. PELs are published in the *NIOSH Pocket Guide to Chemical Hazards*, 1994. Some states (such as California) may have more restrictive PELs. Check state regulations.

b/ TLV = Threshold Limit Value - Time-Weighted Average. Average air concentration (same definition as PEL, above) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), *1994-1995 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.*

c/ IDLH = Immediately Dangerous to Life or Health. Air concentration at which an unprotected worker can escape without debilitating injury or health effects. Expressed as ppm unless noted otherwise. IDLH values are published in the *NIOSH Pocket Guide to Chemical Hazards*, 1994.

d/ When a range is given, use the highest concentration.

e/ Ionization Potential, measured in electron volts (eV), used to determine if field air monitoring equipment can detect substance. Values are published in the *NIOSH Pocket Guide to Chemical Hazards*, June 1994.

f/ Refer to expanded rules for this compound.

g/ mg/m^3 = milligrams per cubic meter.

h/ NIOSH recommends reducing exposure to the lowest feasible concentration, and limiting the number of workers exposed.

i/ Total dust.

j/ Respirable fraction.

k/ NA = Not available.

l/ Olfactory fatigue has been reported for the compound and odor may not serve as an adequate warning property.

m/ (skin) = Refers to the potential contribution to the overall exposure by the cutaneous route.

n/ (ceiling) = Ceiling concentration which should not be exceeded at any time.

o/ Based on fume.

p/ Based on dust.

q/ NIOSH recommends reducing exposure to the lowest feasible concentration, and limiting the number of workers exposed.

r/ Total dust containing no asbestos and less than 1% crystalline silica.